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ABSTRACT

This program planning guide for a two-year postsecondary nuclear reactor (plant) operator trainee program is designed for use with courses 1-16 of thirty-five in the Nuclear Technology Series. The purpose of the guide is to describe the nuclear power field and its job categories for specialists, technicians and operators: and to assist planners, administrators, faculty, and industrial and community educational advisors in establishing and conducting relevant training programs. The guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing, and instructional materials needed for training technicians and operators in this field. Appended material includes the technical specialty courses and module titles and descriptions: suggested workforce needs survey instrument for nuclear technician and reactor operator trainee: equipment list with cost, quantity, and vendor data: and suggested library references and materials. (A master index to the series and other suggested program planning guides are available--see CE 026 856 and CE 026 639-643.) (LRA)

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NUCLEAR TECHNOLOGY SERIES

NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE

A SUGGESTED PROGRAM PLANNING GUIDE

(REVISED JUNE 80)

CE 026 640

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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The Nuclear Technology Series consists of five curricula (see page 2).

Nuclear Reactor (Plant) Operator Trainee.
Radiation Protection Technician.
Nuclear Materials Processing Technician.
Nuclear Quality Assurance/Quality Control Technician.
Nuclear Instrumentation and Control Technician.

The Nuclear Reactor (Plant) Operator Trainee curriculum consists of the following 16 technical specialty courses made up of 114 instructional modules (see Appendix B for module titles and descriptions):

Radiation Physics.
Radiation Protection I.
Principles of Process Instrumentation.
Heat Transfer and Fluid Flow.
Introduction to Nuclear Systems.
Instrumentation and Control of Reactors and Plant Systems.
Reactor Operations
Reactor Safety.
Reactor Auxiliary Systems.
Power Plant Systems.
Radiation Detection and Measurement.
Reactor Physics.
Power Plant Chemistry.
Introduction to Quality Assurance/Quality Control.
Metallurgy and Metals Properties.
Mechanical Component Characteristics and Specifications.

Availability: Instructional modules are available individually or by courses from:

Center for Occupational Research and Development
4800 Lakewood Drive
Waco, Texas 76710
Telephone (817) 772-8972

FOREWORD

In response to the needs of the nuclear power industry, a curriculum has been designed and 114 instructional modules have been developed. These modules may be used by two-year, post-secondary technical institutions to train men and women to work as nuclear reactor (power plant) operator trainees. The instructional materials also are useful to employers for training or updating their employees in company-sponsored educational programs.

The purpose of this Guide is to describe the nuclear power field and its job categories for specialists, technicians and operators, and to assist planners, administrators, faculty and industrial and community educational advisors in establishing and conducting relevant training programs.

The Guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing and instructional materials needed for training technicians and operators in this field. This information is based on task inventories conducted by the Center for Occupational Research and Development staff and on the collective thinking of the National Steering Committee for Nuclear Technician Training, made up of employers, technical specialists and educators.

Funds for this project were provided under contract from the U.S. Office of Education, Bureau of Adult and Occupational Education, Mr. William M. Berndt, Project Officer. Additional assistance in the form of valuable advice, encouragement and guidance was provided by Dr. Walter J. Brooking, Project Monitor.

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Dr. Maurice W. Roney, Texas State Technical Institute.
Mr. W. Scott Fellows, Director of Special Programs,
Southern States Energy Board.

Second, the invaluable assistance of a dedicated National Steering Committee for Nuclear Technician Training merits special acknowledgment: the members of this committee are listed in Appendix A.

Thirdly, the quality and relevance of this curricula and the instructional materials owe much to the technical resource personnel, writers, module reviewers, and editors too numerous to identify by name but who must be recognized in their entirety.

Staff members of the Center for Occupational Research and Development who have contributed significantly to this entire project and the materials contained in this guide include:

Mr. Vernon Woolf, Associate Project Director.
Mr. Ellis Lindsey, Research Associate.
Ms. Kay Liston, Project Coordinator.

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Project Director

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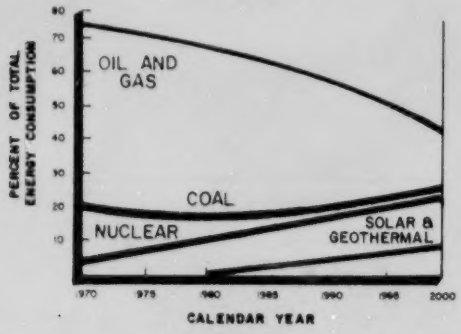
NUCLEAR TECHNOLOGY

Nuclear fission – atom splitting – generates heat, providing an energy source for electrical plants. Its world-wide impact is rapidly increasing. At the beginning of 1980, 67 on-line nuclear-fueled plants provided 13 percent of America's electrical power. By 2000, this percentage will have doubled. And outside the United States, nations on nearly every continent are looking to nuclear fission for electrical power generation.



Projected consumption of various energy sources.

Indeed, nuclear reactors have come of age in the electrical power generating industry. Genuine concerns, embodied in laws and regulations, have required nuclear technology to be among the safest and cleanest processes available for electrical power generation.

Today, nuclear technology, once recognized for only its destructive ability, has become a multipurpose field of endeavor, providing many human services and offering an array of new technical career opportunities.

CAREERS IN NUCLEAR TECHNOLOGY

As a technology, the nuclear field has passed the state of basic research through the phase of applied research and into an era of practical application. The first commercial nuclear electrical power plant (Shippingport, Pennsylvania) came on-line in 1958. But nuclear fission had already proved its capability as a virtually limitless and inexhaustible source aboard the submarine, USS Nautilus – this first nuclear powered vessel began its sea trials in 1955. Many of industry's early nuclear operators and technicians were former seamen from the Navy's extensive nuclear fleet.

The world's first nuclear-powered vessel, the USS Nautilus.

Today, a few technical-vocational schools offer limited nuclear programs. But industry's ability to absorb trained technicians with nuclear skills is barely affected by graduates of these programs. Ingress into industry from the Navy has dwindled to an ineffective trickle.

Recent workforce needs assessments, made and supported by a strong National Steering Committee (Appendix A) composed of employers of nuclear operators and technicians, identified a present (1977) need in industry for half a million people with nuclear skills and knowledge. Also, five major technical occupations in or directly related to electrical power plant nuclear reactor operation were identified:

Nuclear Reactor (Plant) Operator Trainee.
Radiation Protection Technician.
Nuclear Materials Processing Technician.
Quality Assurance/Quality Control Technician.
Nuclear Instrumentation and Control Technician.

The major emphasis of this Guide is preparation of Nuclear Reactor (Plant) Operator Trainees. The educational material described herein offers nuclear-option curricula for individuals working with radioactive materials in each of the five technical occupations. Therefore, a general job description of each of these major technician classifications associated with power plants is included, along with a brief mention of other opportunities in nuclear technology.

POWER PLANT OPERATOR TRAINEE

The nuclear reactor (plant) operator is responsible for proper routine and emergency operation of the facility. This job is the

Source: AIF

Key			
● Operable	72	Reactors with operating licenses	52,396 MWe
○ Under Construction	92	Reactors with construction permits	101,148 MWe
□ Limited Work Authorizations	4	Reactors with limited work authorizations	4,112 MWe
▲ On Order	30	Reactors on order (including 4 units not sited on map)	35,082 MWe
	198	Total	192,738 MWe

Nuclear electrical power plant distribution, December 31, 1978.
(Courtesy U.S. Atomic Forum.)

most critical in the plant from the standpoint of responsibility and licensing requirements. Training, experience and performance under stress all figure into the ultimate selection process by which such an operator is licensed by the Nuclear Regulatory Commission (NRC)

San Onofre nuclear power plant near San Clemente, California.

and employed by an electric utility. (It has been noted that any shutdown, due to accident or operator error, of an average 1000-MWe power plant can result in a minimum revenue loss equivalent to an operator's salary over a ten-year period. Thus, an operator must combine good judgment with exceptional skill – a combination of learned capabilities best founded on adequate technical education and experience.)

Prior to the late 1970's, nuclear-fueled power plants looked almost exclusively to former Navy reactor operators and technicians as the source of their workforce. These Navy-trained personnel had both an appropriate academic background and a related work experience. With considerable specific facility training and technical retraining a successful transition could be made from the Navy to a utility (power plant).

Other nuclear power plant reactor operators have come from fossil-fueled plants. Operators from such plants, though well versed in general power plant operation, almost always lack nuclear-related skills and knowledge. Therefore, they must be given technical preparation as their retraining needs are almost as extensive as those of individuals with no related experience.

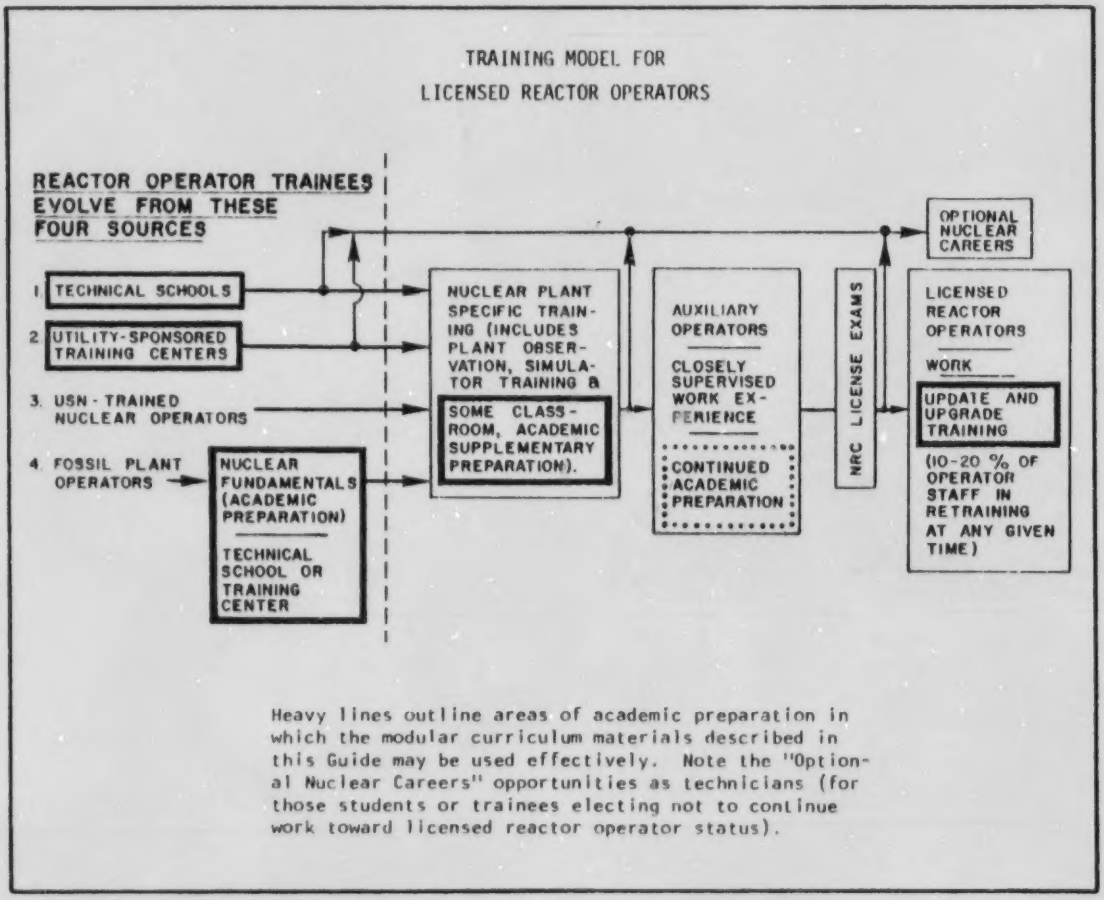
In recent years, the larger utilities have established company or contractor training centers, providing curricula that correlate with on-the-job training to prepare individuals having no nuclear academic or work experience to become reactor operators. These training centers have produced the desired results, but at great costs to the utilities – costs that must eventually be borne by the public.

Now, much of the preparation for reactor operator trainees can be provided by post-secondary, two-year, vocational/technical schools. The modular curriculum materials described in this Guide cover this application. But it applies equally to technical preparation as presented by the training centers and in retraining activities conducted for or within the utilities, as demonstrated by the training model on page 4.

As indicated in the training model and reiterated on page 9, these curriculum materials allow students and trainees to pursue optional careers in nuclear technology.

In addition to nuclear fundamentals, which can be provided by a school, NRC licensing requirements dictate that an operator have experience in the specific plant and on the specialized equipment to be operated. The role of a two-year, post-secondary school program is to prepare nuclear reactor operator trainees who are well grounded in nuclear and power plant fundamentals. Therefore, the materials described in this Guide meet the need for the operator trainee position.

Other technical occupations described


TRAINING MODEL FOR
LICENSED REACTOR OPERATORS
REACTOR OPERATOR TRAINEES EVOLVE FROM THESE FOUR SOURCES
1. TECHNICAL SCHOOLS
2. UTILITY-SPONSORED TRAINING CENTERS
3. USN-TRAINED NUCLEAR OPERATORS
4. FOSSIL PLANT OPERATORS
NUCLEAR FUNDAMENTALS (ACADEMIC PREPARATION)
TECHNICAL SCHOOL OR TRAINING CENTER
NUCLEAR PLANT SPECIFIC TRAINING (INCLUDES PLANT OBSERVATION, SIMULATOR TRAINING & SOME CLASSROOM, ACADEMIC SUPPLEMENTARY PREPARATION).
AUXILIARY OPERATORS
CLOSELY SUPERVISED WORK EXPERIENCE
CONTINUED ACADEMIC PREPARATION
NRC LICENSE EXAMS
OPTIONAL NUCLEAR CAREERS
LICENSED REACTOR OPERATORS
WORK
UPDATE AND UPGRADE TRAINING
(10-20 % OF OPERATOR STAFF IN RETRAINING AT ANY GIVEN TIME)

Heavy lines outline areas of academic preparation in which the modular curriculum materials described in this Guide may be used effectively. Note the "Optional Nuclear Careers" opportunities as technicians (for those students or trainees electing not to continue work toward licensed reactor operator status).

briefly in the following paragraphs are plagued with arrays of job titles but, for simplicity, each is limited to its most common formal title.

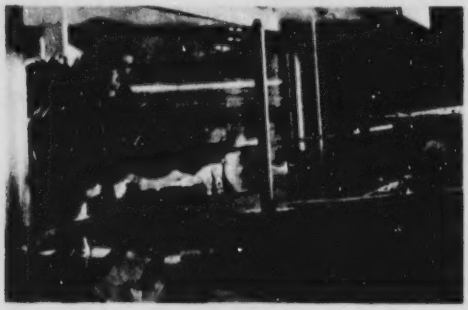
Radiation protection — protection for employees and the environment.

RADIATION PROTECTION TECHNICIAN

An inherent characteristic of energy is its potential for doing harm to life and property if allowed to get out of control. This potential existed with the most primitive uses of fire by man, and it exists in the most advanced applications of nuclear fission. Special care must be taken to prevent uncontrolled nuclear radiation. Skilled technicians must monitor and control radiction levels. Radiation protection technicians measure the intensity and identify types of radiation and contamination.

NUCLEAR MATERIALS PROCESSING TECHNICIAN

This technician performs a variety of tasks related to the milling, conversion, separation and fabrication of nuclear materials and fuels; and he may perform tasks related to fuel reprocessing, waste management, radioactive materials and materials irradiation.



Materials handling requires skill and knowledge.

QUALITY ASSURANCE / QUALITY CONTROL TECHNICIAN

Quality assurance (QA) and quality control (QC) consist of testing, inspecting and auditing materials, equipment and processes to ensure that all are maintained within specified qualitative and quantitative limits.

The QA/QC technician may conduct nondestructive testing of materials or use other methods for inspecting materials and workmanship for compliance with regulations and specifications. Duties may include electrical, civil, mechanical and welding inspection of equipment, materials, processes and structures during construction, operation and maintenance of a power plant.

Trained QA/QC technicians ensure quality materials and workmanship.

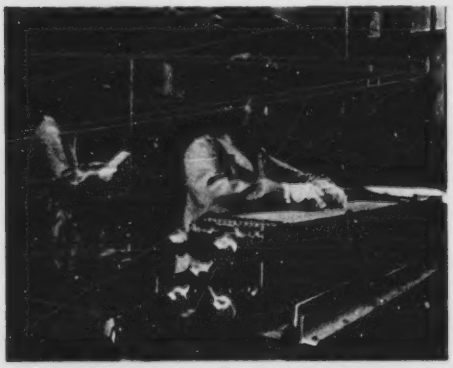
NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN

Instrumentation has long enjoyed its own "technology." A nuclear instrumentation technician must employ all the skills and knowledge attributable to the basic technology plus those unique to nuclear. Duties include inspection, analysis, calibration, repairs, and routine maintenance of instrumentation and control systems (including computer maintenance) throughout the plant.

Calibration, maintenance and repair of nuclear instruments require special training.

OTHER OPPORTUNITIES IN NUCLEAR TECHNOLOGY

In general, job descriptions indicated above apply to the nuclear power plant workforce - the requirements for nuclear technicians are concentrated in this industry; however, equally challenging and rewarding opportunities exist in the vast support and peripheral industries that supply equipment and materials to the utility companies. Also, nuclear research and medicine utilize technicians in large numbers. Thus, applications of the technology, already widespread, continue to expand.



Support industries, such as nuclear fuel rod fabrication, provide job opportunities.

In general, expanding technological applications indicate an expanding workforce requirement. Certainly, this generality holds true for the nuclear field.

NATIONAL WORKFORCE REQUIREMENTS

Nuclear power plants span the nation and much of the developed world. And, because the nuclear technology workforce requirements and growth applicable to this Guide appear proportional to nuclear power production, the existence and foreseeable expansion of nuclear plants may be used as a needs assessment base.

In 1970, Wayne L. Rodgers, Director of Eastern Idaho Vocational School (Idaho Falls) correctly prophesied:

> The heaviest employment of nuclear technicians is with the Federal government. However, the distribution in employment is shifting toward reactor operators, fuel processors, and reactor vendors and manufacturers.

As of early 1979, Nuclear Regulatory Commission (NRC) licenses were valid for 1482 senior reactor operators and 1069 operators. (In their published lists, NRC makes no distinction between power plant reactor operators and operators of research reactors.) Reactor operator projections for the period 1979 through 1987 suggest an increase from the current total of about 2500 to well over 6000. This increase suggests an annual need for at least 1200 trainees to provide an average of about 700 new licensed reactor operators to meet the needs of growth requirements and attrition. Needs analyses indicate similar workforce requirements throughout the nuclear industry.

To support these operators, at the technician level only, all the jobs described previously also must be filled.

KNOWLEDGE AND SKILLS REQUIREMENTS FOR REACTOR OPERATOR TRAINEE

A significant element of any needs assessment is a determination of the specific skills graduate technicians must possess to complete those tasks they might reasonably be expected to perform (sometimes these requirements are referred to as entry-level skills). These determinations must identify the minimum knowledge and skills a student should acquire prior

to graduation. The NRC-specified guidelines for reactor operators include:

- A combination of education and power plant fundamentals.
- Work experience at the specific reactor.
- Training on a simulator or the reactor to be operated.
- A license awarded by the NRC after successful completion of extensive written and oral testing (and including physical and psychological examinations), tailored to the specific facility to be operated.

Though NRC does not establish mandatory training requirements, it does audit training programs to be sure potential operator-license applicants receive appropriate fundamental grounding in the following subjects:

- Principles of reactor operation.
- Design features of nuclear power plant.
- General operating characteristics of nuclear power plant.
- Instrumentation and control systems.
- Safety and emergency systems.
- Standard and emergency operating procedures.
- Radiation control and safety provisions.

To meet the minimum educational requirements for a senior operator license, the candidates not only must understand "what" is happening in the operation of a reactor facility, but "why." A senior operator directs the activities of other licensed operators. (Note: Licenses expire after two years. Renewal requires the licensee to again demonstrate competence.)

The NRC examination emphasizes comprehension and practical theory — memorization cannot carry an applicant through a licensing examination.

The following list includes those skills and areas of knowledge required to pass an NRC nuclear plant operator's licensing examination. Part of what is required must come from on-the-job training and simulator experience. An asterisk (*) identifies those items applicable to a trainee that could be covered in an educational program at a two-year institution; the curriculum presented in the Instructional Program section, which follows, is based on those items only.

*Fundamentals of reactor theory, including: fission process; energy release; neutron multiplication; source effects; control-rod effects; and criticality indications.

*Design features of course, including: core structure; fuel elements; control rods; core instrumentation; and coolant flow.

*Mechanical design features of the reactor primary system, steam system, condensate and feedwater control systems, and auxiliary systems.

*General operating characteristics, including: causes and effects of temperatures; pressure and reactivity changes; effects of load changes; and operating limitations and reasons for them.

*Design, components and functions of reactivity control mechanisms.

*Design, components and functions of safety systems, including: instrumentation; signals; interlocks; and automatic and manual features.

*Components, capacities and function of reserve and emergency systems.

*Shielding, isolation and containment design features, including access limitations.

Standard and emergency operating procedures for the facility/plant (specific).

Purpose and operation of radiation monitoring system, including alarm and survey equipment (specific).

Radiological safety principles and procedures (specific).

Pre-startup procedures for the facility, including associated plant equipment that could affect reactivity (specific).

Source and significance of annunciator signals, and conditions indicating these signals and responsive remedial action.

Instrumentation systems and the source and significance of reactor instrument readings (specific).

Behavior characteristics of specific facility.

Control manipulation required to obtain desired operating results during normal, abnormal and emergency situations (specific).

*Significance of radiation hazards, including: permissible levels; levels in excess of those authorized; and procedures to reduce excessive levels and guard against personnel exposure.

Use and function of specific facility's radiation monitoring system, including: fixed radiation monitoring system; alarms; portable survey instruments; and personnel monitoring equipment.

Emergency plan for specific facility, including: operator's responsibility to decide whether or not the plan should be executed; and duties assigned under the plan.

Necessity for a careful approach to the responsibility associated with safe operation of the specific facility.

*Radiation waste operation.

*Regulations (10CFR 19, 20, 50, 55, and 100).

*Licensing process.

Conditions and limitations of facility license or authorization (specific).

Design and operating limitations in the technical specifications for facility (specific).

Operation of facility heat removal system including: primary coolant systems, emergency coolant systems, decay heat removal systems, steam systems, condensate and feedwater systems, and relation of the proper operation of these systems to operation facility.

Startup and control cooperation of nuclear reactor in which heat is used to produce steam for the purpose of generating electricity, and/or process steam.

Monitor instruments and record data in control room to control chain reaction, steam production and auxiliary systems.

Procedures and limitations involved in initial core loading, alternations in core configurations control-rod programming, determination of various internal and external effects on core reactivity.

Fuel-handling facility, procedures and refueling techniques.

Procedures and equipment available for handling and disposal of radioactive materials and effluents.

To meet these licensing requirements, extensive on-the-job experience is essential. To qualify for on-the-job experience, an operator trainee should be well grounded in the fundamentals of nuclear reactor and power plant technologies.

Initial preparation of nuclear reactor operator trainees is the natural province of two-year, post-secondary schools. Employers have borne the brunt of training effort in this field until now, but such basic educational programs are at variance with their inhouse training role. Thus, assumption of a strong role by schools would be an appropriate move toward proper realignment of nuclear technical education.

Such a move should lift an unnatural burden from industry (pre-entry level training), open new opportunities for successful instructional programs to schools, open new career opportunities to students and add stability to communities in which such schools and industries are situated.

Program requirements — faculty, facilities, equipment, supplies and cost estimates — (discussed in the following section) include classroom-laboratory-office-storage floor space and a department head with appropriate technical comprehension and industrial experience. Also, such a program calls for a quality curriculum and appropriate instructional materials.

INSTRUCTIONAL PROGRAM

The curriculum described in this section was derived from the task inventory described in the first section.

CURRICULUM

The Nuclear Reactor (Plant) Operator Trainee curriculum incorporates learning objectives and supporting objectives based upon related knowledge as well as the tasks the operator (or technician) is expected to perform in industry today.

Even though the curriculum design specifically relates to training nuclear plant operator trainees, every course and every module invites multiple application, as demonstrated in the chart on page 12.

An example of the curriculum is indicated below.

NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE CURRICULUM

First Quarter	Periods/Week Class	Lab	Total
Introduction to Nuclear Technology	2	3	5
*Radiation Physics (Course 1)	3	3	6
Mathematics I	3	2	5
Fundamentals of Electricity and Electronics	3	3	6
Introduction to Technical Communications	2	2	4
Elective	1	0	1
	14	13	27
Second Quarter			
*Radiation Detection and Measurement (Course 11)	3	4	7
Chemistry I	3	6	9
*Radiation Protection I (Course 2)	3	3	6
Mathematics II	3	2	5
	12	15	27
Third Quarter			
Basic Mechanics	3	3	6
*Introduction to Quality Assurance/Quality Control (Course 14)	2	3	5
*Principles of Process Instrumentation (Course 3)	3	3	6
*Heat Transfer and Fluid Flow (Course 4)	3	3	6
*Metallurgy and Metals Properties (Course 15)	3	3	6
	14	15	29

Fourth Quarter	Periods/Week Class	Lab	Total
Technical Writing	2	3	5
*Introduction to Nuclear Systems (Course 5)	3	4	7
Blueprint Reading	1	3	4
*Mechanical Component Characteristics and Specifications (Course 16)	3	3	6
*Reactor Physics (Course 12)	3	4	7
	12	17	29
Fifth Quarter			
*Reactor Safety (Course 8)	3	2	5
*Power Plant Systems (Course 10)	3	4	7
*Instrumentation and Control of Reactors and Plant Systems (Course 6)	2	3	5
*Power Plant Chemistry (Course 13)	3	3	6
Elective	3	3	6
	14	15	29
Sixth Quarter			
Special Projects	4	8	12
*Reactor Operations (Course 7)	3	3	6
*Reactor Auxiliary Systems (Course 9)	3	3	6
Elective	3	3	6
	13	17	30

*Technical specialty courses for which instructional modules have been developed.

COURSE DESCRIPTIONS

Each course in the curriculum is described to indicate both its content and its relevance to the overall program.

FIRST QUARTER

Introduction to Nuclear Technology. An introduction to the principles and applications of nuclear energy. Student is introduced to basic principles involved in nuclear radiation, nuclear sources, reactors and fuel cycles. Essential features of a nuclear power plant are discussed. Student also learns how radionuclides and radiation have application in industry and medicine. Nuclear safety will be emphasized and radiation effects evaluated. Lab sessions will include field trips, films and guest speakers. (Note: Materials for this course should be obtained from nuclear utility public relations offices.)

*Radiation Physics. An introductory course in basic concepts of nuclear radiation. Main topics covered include atomic and nuclear structure, radioactivity and interaction of radiation with matter. Student is introduced to basic radiation and measuring instruments, including Geiger-Müeller counters and personnel monitoring devices.

Mathematics I. A course in algebra, geometry and introductory trigonometry. Includes ratios, linear equations, plotting, reading and interpreting graphs and sinusoids. Math labs are problem sessions, preferably conducted by the nuclear faculty.

Fundamentals of Electricity and Electronics. A study of basic principles of direct current and alternating current, series and parallel circuit analyses utilizing Ohm's and Watt's laws, basic motors, generators and relays, solid state, etc.

Introduction to Technical Communications. An introduction to the nature of communication skills and thinking processes with practical exercises in writing, reading, speaking, spelling and vocabulary as related to technical areas. Emphasis on writing, making reports and utilizing the use of a memoranda.

Elective.

---

*Technical specialty courses.

SECOND QUARTER

*Radiation Detection and Measurement. A course in principles and methods used to detect and measure radiation, with emphasis on ionization and scintillation detectors. Statistics of counting will be introduced. Properties of α, β and γ will be studied.

Chemistry 1. Basic chemical principles are introduced, using modern laboratory techniques to demonstrate concepts, including atomic structure of matter, formulae, composition and bonding, the electrical nature of matter, acids, bases, oxides, salts and salt solutions.

*Radiation Protection I. An introductory course to familiarize student with the field of radiation protection, the art and science of protecting human beings from injury by radiation. Specific topics include dose and exposure measurements and units, biological effects of radiation, Federal Regulations of exposures and internal exposure evaluations.

Mathematics II. A continuation of Mathematics I; algebra includes logarithms to base 10 and base e and exponentials; geometry and trigonometry emphasizing slopes, rates of change and solutions of equations and problems with transcendental functions.

THIRD QUARTER

Basic Mechanics. An introductory course in mechanics, to teach mass, force, acceleration, velocity, momentum, energy, power and conversion of units.

*Introduction to Quality Assurance and Quality Control. An introductory course in quality assurance and quality control, including such topics as history and purpose of quality control, terms and definitions, codes and standards, publications and quality assurance/quality control procedures.

*Principles of Process Instrumentation. A course to teach principles of operation, calibration and maintenance of process instrumentation found in electrical power generating plants (includes all non-nuclear instrumentation). Specific topics include flow, temperature and pressure instrumentation.

*Heat Transfer and Fluid Flow. A basic study of heat transfer and fluid flow processes that take place in nuclear reactor systems. Natural convection, forced convection, thermal radiation, nucleate boiling and film boiling are covered.

*Metallurgy and Metals Properties. An introductory study designed to acquaint student with basic metallurgical concepts and metals properties. Many basic physical properties are discussed and related to the behavior of metals and alloys. A preliminary study of metal structure is initiated. Properties of stainless steel and carbon steel are stressed. Student will be introduced to destructive examination techniques, including nick break, bend, tensile, hardness, impact, fatigue and microsectioning.

FOURTH QUARTER

Technical Writing. A study of effective ways of presenting information with emphasis on the use of logs, keeping of records and notebooks, use of graphs, drawings and sketches, and various types of reports.

*Introduction to Nuclear Systems. Course includes basic understanding of all major components of the reactor core, pressure vessel, shielding, and primary cooling water systems. Differences between PWR's and BWR's are discussed. The basic nuclear fuel cycle and handling systems are discussed.

Blueprint Reading. A basic study of industrial blueprints, process flow sheets, piping symbols and instrumentation symbols, schematics, logic diagrams and computer circuitry.

*Mechanical Component Characteristics and Specifications. A course designed to acquaint student with mechanical components and equipment found in an electrical power generating plant or similar industrial facility.

*Reactor Physics. A basic course in the principles of nuclear reactor operation, including fission process, neutron balance, neutron slowdown, criticality and reactor kinetics. Actual characteristics of an operating nuclear power reactor are discussed. (It is highly desirable to use a nuclear reactor or simulator in this course, both as a neutron source in conducting experiments and as a means of gaining hands-on experience.)

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*Technical specialty courses.

FIFTH QUARTER

*Reactor Safety. Discussion of entire licensing procedure, including writing of safety reports. Also given are methods and functions of safety analyses, with technical specification limits interpreted, and including engineered safeguards.

*Power Plant Systems. A study of "balance of plant" – that part of the electrical generating plant common to both nuclear plants and fossil plants. Includes power plant thermodynamics, mechanical equipment (pumps, valves, pipes and heat exchangers), electrical equipment (including generating equipment, transmission lines, plant distribution and protection devices) and plant maintenance.

*Instrumentation and Control of Reactors and Plant Systems. A study of nuclear reactor instrumentation systems, nuclear plant controls, control element drive mechanisms, design and operation characteristics of electrical control systems, turbine generation interfaces, and electrical distribution and reactor regulating systems.

*Power Plant Chemistry. A course designed to introduce student to chemistry of fossil and nuclear power plants, including water properties, water treatment and purification, and primary coolant chemistry programs. Gaseous and liquid radioactive waste handling should be discussed briefly.

Elective.

SIXTH QUARTER

Special Projects. This course is designed to allow the student to achieve a higher degree of specialization than would otherwise be possible. Work must be on a project closely related to student's chosen specialty. This course should be taken last school quarter.

*Reactor Operations. A course designed to familiarize student with the actual operation of reactors, which can best be accomplished by either actual operation of a reactor, or on a simulator, or through visits to an operating reactor.

*Reactor Auxiliary Systems. A course designed to orient student to the design criteria, operating parameters and systems interfaces of the reactor coolant system, chemical and volume control systems, safety injection systems, refueling systems, control element drive mechanisms, radioactive waste systems and disposal and emergency power systems.

COURSE OPTIONS

As noted previously, almost any nuclear-related training program could utilize material from the model curriculum. Nuclear technology options for these technicians are illustrated in the chart below. Courses 1, 2, 11 and 14 are common to each of the five technology curricula. Numerous other courses are common to two or more of the curricula.

At least two program options or specialties are recommended at schools for several reasons. 1) Reactor operator job requirements (based on NRC regulations) exclude some students for reasons other than educational non-achievement; i.e., personality traits. 2) A temporary shift in workforce requirements may favor an option. 3) Student interest may change after the first year of co-op experience.

NUCLEAR TECHNOLOGY PROGRAM INSTRUCTIONAL MODULES

Modular instructional materials for the five nuclear occupations are listed below, grouped according to courses. Courses used in the curriculum of a particular occupation are identified by a number in the appropriate column, suggesting school quarter for use of the courses.

COURSE NO.	TECHNICAL COURSE TITLE	NUMBER OF MODULES	NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE	RADIATION PROTECTION TECHNICIAN	NUCLEAR MATERIALS PROCESSING TECHNICIAN	NUCLEAR QUALITY – ASSURANCE/QUALITY – CONTROL TECHNICIAN	NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN
1	Radiation Physics	6	1	1	1	1	1
2	Radiation Protection I	6	2	2	2	2	2
3	Principles of Process Instrumentation	8	3		3	3	3
4	Heat Transfer and Fluid Flow	9*	3				4
5	Introduction to Nuclear Systems	6	4	3		4	4
6	Instrumentation and Control of Reactors and Plant Systems	6	5				5
7	Reactor Operations	7	6				
8	Reactor Safety	5	5				
9	Reactor Auxiliary Systems	4	6				
10	Power Plant Systems	9	5				
11	Radiation Detection and Measurement	6	2	2	2	2	2
12	Reactor Physics	8	4				4
13	Power Plant Chemistry	7	5	4			
14	Introduction to Quality Assurance/ Quality Control	9	3	3	3	3	3
15	Metallurgy and Metals Properties	8	3		4	3	
16	Mechanical Component Characteristics and Specifications	8	4			4	
17	Radiation Protection II	5		4	4		
18	Radiological Emergencies	7		4			
19	Radiation Shielding	6		6			
20	Radiation Monitoring Techniques	7		5	5		
21	Radioactive Materials Disposal and Management	7		5			
22	Advanced Radionuclide Analysis	7		6			
23	Nuclear Chemical Processes	7			5		
24	Nuclear Systems and Safety	6**			6		
25	Radioactive Material Handling Techniques	8***			6		
26	Nondestructive Examination (NDE) Techniques I	7				4	1
27	Metrology	8			3	3	
28	Welding Inspection	11				5	
29	Civil/Structural Inspection	8				5	
30	Mechanical Inspection	9				5	
31	Quality Assurance Practices	8				6	
32	Nondestructive Examination (NDE) Techniques II	6				5	
33	Control Systems I	6					5
34	Control Systems II	7					6
35	Power Plant Electrical Systems and Components	7					6

*Course 4 modified for I&C only

**Module 24-1 is 12-1
24-2 is 12-2
24-3 is 12-3

***Module 25-6 is 21-1
25-7 is 21-6
25-8 is 21-4

NOTE: Numbers in columns denote suggested quarter for use of the courses.

INSTRUCTIONAL MATERIALS

The basis of a sound instructional program is well prepared materials. If scrupulously reviewed by educators and employers, revised and tested, such materials best serve the instructional program, the students and the ultimate employers. The best materials also meet stringent content requirements for flexibility, relevance, currency and validity.

MATERIAL CONTENT

As noted earlier, nuclear technology encompasses a variety of technical job opportunities with equally great variations in knowledge-and-skills requirements. A curriculum that offers a two-year reactor operator trainee program with options for several nuclear-related jobs must be flexible enough to be adapted to specific employer needs on a local basis. Modular materials allow pin-point selection of appropriate instructional units; for example, the instrumentation technician, whose major involvement is with instruments, with only an incidental involvement in nuclear, should be allowed to select those instructional units applicable to that limited involvement. The flexibility of brief, single-subject, self-contained modules allows a curriculum – whether a seminar, short course, course option or full course – to be custom designed to meet specific needs.

The curriculum material is passed through a variety of critical reviews to ensure its relevancy. Local instructional needs, determined by a local or regional needs assessment and task inventory, make selection of material relevant to local, current needs possible.

Historically, technical instructional materials have evolved slowly. Too often, materials became available at about the same time they became obsolete. To eliminate this problem, the materials described in this Guide are being offered within months – sometimes, weeks – following their initial preparation by authors and reviewers involved in the state-of-the-art technology. Further, through continuing efforts of the National Steering Committee for Nuclear Technician Training, technological advances as well as national employment opportunities are reviewed and relevant data is passed on to institutions and organizations using the materials.

The materials are updated as necessary to ensure currency. The most effective manner of ensuring currency, however, is for users of the material to utilize their local industrial advisory committee (IAC) to keep the local program up to the minute on technological changes, variations and workforce requirement fluctuations. (Note: An IAC is described in the following section in detail.)

From the educator's standpoint, educational materials must assume a valid educational format. In this case, the materials are presented in a strictly cognitive form; that is, objectives are stated in "action" terms (perform, calibrate, draw, list, measure), and each module as well as its procedures emphasizes manipulative skills, founded on valid, relevant theory and practice.

Thus, each module, as well as the entire curriculum for nuclear reactor (plant) operator trainees (and technicians), consists of valid, current, relevant and flexible materials.

MODULE ELEMENTS

Instructional modules developed specifically for this nuclear reactor (plant) operator trainee curriculum contain these basic elements:

Introduction: Identifies topic (and often includes rationale for studying the material).

Module Prerequisites: Identifies knowledge and skills students should possess before studying the module.

Objectives: Clearly identifies what the student is expected to know and do upon completion of module. Objectives are stated in terms of action-oriented behaviors, including such terms as "operate," "measure," "calculate," "identify" and "define," instead of words with many interpretations, such as "know," "understand," "learn" and "appreciate."

Subject Matter: Presents background, theory and techniques supporting the objectives. (Subject matter is written with the technical student in mind.)

Exercises: Provides practical problems to which student can apply new knowledge from module study.

Materials: Identifies equipment required to complete laboratory procedures.

Procedures: Presents experiments or "hands-on" activities, including step-by-step instructions. (Experiments are designed to reinforce student learning.)

Data Tables: Included in most first-year or basic-course modules, the data tables help students learn how to collect and organize data.

Reference Materials: Presents suggestions for supplementary reading.

Test: Measures each student's achievement against objectives stated at the beginning of the module.

Modules average approximately 30 typewritten pages, including illustrations. (Illustrations normally are line drawings that are easily understood and can be reproduced on copy machines for overhead projection.) New modules can be added easily, or existing ones modified, for self-paced instruction or short courses.

A description of the courses and their modules appears in Appendix B. Course and module titles of planned materials for the other four curricula (Courses 17-35) are indicated also.

An exhaustive index for each course is scheduled for completion in August, 1980. In addition to this index in the back of each course, a general index to all 35 courses will be available in a separate volume. These indexes will be excellent aids (1) for planners who wish to determine the exact content of each module or course, (2) for students and instructors who must locate materials in the various courses, and (3) for researchers who use the courses as library or plant references.

INDUSTRY TRAINING PROGRAM

Planning a training program within an industry differs from institutional planning — employer needs dictate program content. The following examples of industrial preparation programs for nuclear operator trainees show various approaches, all of which have proved to be effective.

DUKE POWER COMPANY OPERATOR TRAINING PROGRAM

The Duke Power program content is based on the needs of a new employee with no power plant experience or training. The following chart depicts advanced placement of trainees with particular backgrounds. Graduates of two-year nuclear technology programs are placed on the same level as ex-military nuclear personnel.

Duke's basic program spans 49 weeks. The advanced portion (81+ weeks) involves on-the-job and license preparatory training, with little time spent in the classroom.

DUKE POWER COMPANY OPERATOR TRAINING PROGRAM FOR VARIOUS BACKGROUNDS

	BASIC				ADVANCED			
Background	OR	SCG	SCS	NP	NF	SPS	SIM	LP
Fossil Plant	X		P	X	X	X	X	X
Technical School Graduate/ Military Nuclear	X		P		P	X	X	X
Power Plant Licensed Operator	X					X	X	X
Engineering Graduate	X	X	P	Excpt NE X	Excpt NE X	X	X	X
Non-trained/Non-experienced	X	X	X	X	X	X	X	X

LEGEND:
OR Orientation
SCG Systems and Components (General)
SCS Systems and Components (Specific)
NP Nuclear Preparatory
NF Nuclear Fundamentals
SPS Systems and Procedures (Specific)
SIM Simulator
LP License Preparatory
X All Topics
P Partial or Short Course
Excpt NE Except Nuclear Engr.

Parallel topics of study for Duke trainees in the basic program and the nuclear materials described in this Guide (Appendix B) include:

Systems and Components (General): Courses 3, 9, 10, 13.

Systems and Components (Specific): Courses 4, 5, 6, 12, 13, 16.

Nuclear Preparatory: Courses 1, 2, 5, 6, 11, 12, 15.

Also, several modular courses encompass material covered in the advanced portion of Duke's program:

Nuclear Fundamentals: Courses 3, 4, 8, 10.

License Preparatory: Courses 7 and 14.

DUKE POWER COMPANY NUCLEAR OPERATOR CURRICULUM

	Weeks	Parallel CORD Course Number
General Station Training:		
Orientation	1	
Basic Training:		
Systems & Components (General)	2	3,9,10,13
Systems & Components (Specific)	24	4,5,6,12,13,16
Nuclear Preparatory	12	1,2,5,6,11,12,15
Advanced Training:		
Nuclear Fundamentals	11	3,4,8,10
Systems & Procedures (Specific On-the-Job Training)	46	
License Preparatory – Operator	24	7,14
License Preparatory – Senior Operator		

BABCOCK AND WILCOX OPERATOR TRAINING PROGRAM

The complete B & W program consists of seven courses designed as a package to fulfill NRC "cold" operator license requirements. Included in the typical nine-month instructional program are courses in basic nuclear theory, observation experience, systems description, simulator operation and pool reactor operation. An eleven-week on-the-job coordination period for trainees, supervised by B & W instructors, is optional.

The modular nuclear curriculum described in this Guide covers all areas of basic nuclear theory and system description, while lending itself to those institutional or industrial programs with a simulator access.

Materials provide a basis for curriculum planning; however, this Guide recognizes that much more goes into the creation of a successful training program. In the Planning a Program section, total program planning is discussed.

BABCOCK AND WILCOX OPERATOR TRAINING PROGRAM

	Weeks	Parallel CORD Course Number
Basic Nuclear Theory:		
Mathematics, atomic physics, reactor physics, heat transfer, introductory nuclear instrumentation, shielding and health physics.	13	1,2,4,6,12
Practical Observation Experience.	8	
Nuclear Steam Supply System & Operations.	4	7,9,10
PWR Simulator Operation.	8	
Reactor Operation (at least 10 startups).	2	
On-the-Job Coordination.	44	

TVA OPERATOR TRAINING PROGRAM

The basic TVA program (Phase I, II and III) spans 16 months, with each day divided into 3 1/2 hours of classroom instruction and 3 1/2 hours of inplant observation.

The operator trainee is a TVA employee, but may be dismissed for failure to pass any one training phase examination.

Topics of study for TVA reactor operator trainees have content parallel to courses and modules suggested in this Guide.

TENNESSEE VALLEY AUTHORITY (TVA) NUCLEAR REACTOR OPERATOR TRAINING PROGRAM

Phase	I 5 Mo	II 5 Mo	III 6 Mo	Parallel CORD Course Number
Cleaning	15	10	10	8
Safety Practices				
Ind. Safey	10			
Rad. Safety	60	10	10	1,2,11
Operating Procedures	15	36	40	7,6
Reactors and Auxiliary Equipment	24	70	210	5,9,12
Plant Records	10	8	5	14
Feedwater System	33	85	80	4,13
Steam Turbines and Condensers	10	136	10	10
Fuel Handling	0	29	60	7
Radioactive Waste	0	24	50	13
Miscellaneous Plant	27	120	30	
Meters and Instruments	15	35	25	3,6
General Inspection	23	5	15	14
Miscellaneous	13	40	5	15
Controls – Interlocks	25			16
Transmission – Substation	50		20	10
Generators – Exciters	35		20	10
Auxiliary Electric Equipment	35		20	10
Technical Instruction	400	192	350	
Total Hours	800	800	960	

Classroom/Plant Observation/ Simulation

GENERAL ELECTRIC BWR OPERATOR TRAINING PROGRAM

The GE BWR Operator Training Program is designed to meet "cold license" eligibility standards of ANSI/ANS-3.1-1978, ANSI/N18.1-1971, USNRC Regulatory Guide 1.8, 10CFR50, and 10CFR55.

The core of this program consists of five-week BWR Simulator Technology and ten-week BWR Simulator Control Room training packages. The program is based on a foundation of knowledge presented in a sixteen-week Reactor Fundamentals course and is in conjunction with a BWR Observation Training Program of four weeks duration. The BWR Observation Training Program may serve as a prerequisite for the BWR Simulator Control Room Training Module.

In addition, General Electric offers Plant-Specific BWR System Training, generally three to five weeks in length, and Refresher Training programs of varying lengths.

These programs, along with on-the-job training tasks and startup experience provided by employers, prepare the license candidate in all categories of the NRC examination.

GENERAL ELECTRIC BWR OPERATOR TRAINING PROGRAM

Course	Weeks	Parallel CORD Course Number
Reactor Fundamentals	15/16	1,2,4,5,6,13
Mathematics, Chemistry, Electrical Theory, Fluid Dynamics and Mechanical Theory, Thermodynamics and Heat Transfer, Reactor Engineering and Radiation Protection		
Startup Experience		
At least 10 startups at research or test reactor facility (not arranged by GE)		
BWR Simulator Technology	5	
1) Provides instruction in design and operation of systems and components of simulated BWR nuclear power station		
2) Provides basis for observation training		
BWR Observation Training	4	
1) Provides student orientation to the day-to-day operation of a BWR		
2) Provides instruction and familiarization with related BWR Systems		
BWR Simulator Control Room Training	10	
1) Provides development of manipulative skills		
2) Establishes student understanding of integrated plant operation		
3) Provides exposure to off-normal operating conditions		
Plant-Specific BWR Systems Training	5	7
Provides application of BWR knowledge to facility on which candidate is to license		
Refresher Training	Various lengths	
Provides a structured review prior to license examination		
OJT Tasks and Preoperational Testing		

Modular curriculum materials adapt readily to such industrial training programs. Also, they fill the need for less comprehensive short courses and seminars presented by industry or technical associations and intended for updating or upgrading employees.

Module procedures are directed primarily toward students at two-year institutions who have no experience or familiarity with specialized equipment. When an employer uses the instructional modules for employee retraining, the procedures or lab activities should be selectively omitted or replaced.

COOPERATIVE EDUCATION

This technology is adaptable to a cooperative arrangement: a plan which offers important advantages to students, to the school, and to employers of technicians. A cooperative education program provides an opportunity for a student to learn through coordinated study and employment experience. Students alternate periods of attendance at the institution where they study their technical program with periods of supervised employment in business or industry, which provides both training and work experience. The employment constitutes an essential element in their education. The students' employment should be closely related to the field of study in which they are engaged.

When students test their knowledge of theory in a work situation, study becomes more meaningful. Co-op students learn not only the essentials of the technology but also the importance of reliability, cooperation, and judgment as an employed worker in a chosen occupational field.

Co-op students' career choices are stimulated and strengthened by work experiences. A satisfactory work experience provided in a co-op program assists in stimulating the students' interest and effectiveness in the institutional phase of the program, making it more meaningful. The experience in a co-op program also assists students in knowing if they have made the proper occupational choice prior to completing their educational program and entering employment.

A class of students in cooperative technical programs usually spends the first semester or the first two quarters in school; then time is divided so that half the students have a semester or quarter of employment experience while the other half continues to study During the next semester or quarter, the half who have worked return to their formal studies at school while the other half are employed. They usually alternate again so that each student has two semesters or at least two quarters of work experience in the program. The students' technical program is lengthened beyond the curriculum outlined in this Guide by an amount of time equal to the total length of the employment experience.

Specific employment is obtained, as circumstances permit, by the educational institution with the cooperation of the student. The institution regards the work-experience program as an integral part of the technician program as a whole. It is not regarded primarily as an opportunity for earning, although each student while working is paid at the prevailing wage scale for the job performed. Work reports by both the student and the employer are submitted to the school work program coordinator.

The cooperative work-experience program is an opportunity for the students to gain directly related experience, which makes them more valuable as employees. As a result of the work-experience in particular establishments, many students are offered permanent positions upon completion of schooling. Cooperating establishments agree, however, not to make offers of employment that become effective before a trainee completes the program.

Cooperative programs provide opportunities for the educational institution to maintain

close contact with employers in their various programs. This contact becomes a two-way channel of communication, which helps the educational institution keep its knowledge of specific employer needs in each technical field up to date. At the same time, it keeps employers acquainted with and involved in the institution's program(s).

PLANNING A PROGRAM

Planning should begin with establishment of an advisory committee and a determination of needs, followed by an evaluation of local potential for meeting such needs.* Considerations include:

Faculty.
Student Selection and Services.
Facilities.
Equipment.
Library.
Cost.

The extent and implications of each of these considerations are explored following the discussion of needs.

NEEDS DETERMINATION AND EVALUATION

By using accumulated data and a local industrial advisory committee, a program planner may develop a preliminary local or regional needs determination. The needs determination should consist of a survey documenting: number of existing employers; number of job vacancies; number of expected vacancies in 2, 5 and 10 years; other titles given this same job; job entry specifications; type of need — whether for new employees or retraining of existing employees; and anticipated salary range. A typical survey document is shown in Appendix C.

Once a program-sustaining need is determined, the planning considerations listed earlier should be given detailed attention.

ADVISORY COMMITTEE

The success of this program depends, to a great extent, on the formal and informal support of an advisory committee. This committee should be appointed by the chief administrative officer of the institution and should be comprised of local (or regional) employers of reactor operators and technicians. These members serve without compensation. The committee normally consists of about ten members who should serve from two to three years with staggered terms.

The local advisory committee should assist in studies to determine and define the following: the need for the technical assistant program; the knowledge and skills technicians will require; employment opportunities; available student enrollment; curriculum content; faculty qualifications; laboratory facilities and equipment; resources both within and outside the institution; and, cost and financing of the program. If the survey indicates that a program should be initiated, and will be supported, the committee's help in planning and implementing it is invaluable.

The survey should take a form other than an informal question or two to associates of the committee members. It is suggested that a needs assessment instrument (similar to the one shown in Appendix C) be distributed to the employers in the region around the training institution. The form does not have to be elaborate and could be derived from performance objectives stated in this Guide. A checklist of performance objectives, filled out by various employers, gives the school a rather clear outline of the knowledge and skills needed by a trainee to be hired in the community.

When the survey instruments are returned to the school, they should be compiled for use in a task inventory for the occupation. A review of the task inventory by the advisory committee is essential at this point. Resurveying at periodic intervals and changing course content accordingly

*In addition to the "ideas" presented in this Guide to facilitate curriculum planning, members of the project staff and the National Steering Committee are available for consultation and assistance in planning (and implementing) a nuclear program.

keeps the training program up-to-date and ensures that trainees have a better chance for employment. In today's world of specialized skills and employment, the old concept of curriculum by guess or by past procedure is a disservice to the student and to the training institution.

The advisory committee should understand that the program is not intended to make individual students proficient in all duties they might be asked to perform at all types of nuclear reactors. Proficiency in highly specialized work comes from experience and further education, or both. It is impossible to accurately predict the rate of change within various work situations. Employers should expect to provide reasonable on-the-job orientation to acquaint the new employee with operational procedures of the facility.

Upon implementation, the committee provides continuing liaison between the institution and employers. Frequently, the committee helps administrators obtain local funds and state and Federal support for the program. The committee also aids in placement of graduates of the program and in evaluating the performance of the graduates on the job. Such evaluations often indicate minor modifications that more closely align the program with employment requirements and opportunities.

The committee should meet as regularly as needed and should keep formal minutes of its proceedings (which could become, in compilation, an annual report of the proceedings). For further elaboration on the role and responsibilities of the advisory committee in technical education programs, refer to Riendeau's Advisory Committees for Occupational Education: A Guide to Organization and Operation.*

This Guide, designed primarily for planning and development of full-time programs in post high school institutions, can be used by the administrator of the institution and an advisory committee as a starting point for development of their own program. It can and should be modified where necessary and adapted to meet local needs and institutional criteria.

FACULTY

The effectiveness of the program and the curriculum depends largely upon the competence and enthusiasm of the teaching staff. With a qualified and interested faculty, a needed educational program may flourish. Qualified faculty members may exist at the institution or within the industry or organization planning the program, or it may be necessary to recruit a faculty from outside sources. In any event, faculty consideration includes these recommended items:

Numerical Requirements. The number of faculty members needed is based on the duties assigned each member, number of students in the program (first and/or second year) and number of courses scheduled for instruction. The typical teaching load is 18 — 24 class/lab hours per week with the department head assigned not more than 12 hours, allowing time for administrative duties. In the first year, the department head would be responsible for instruction of 24 students. A full-

*Albert J. Riendeau. Advisory Committees for Occupational Education: A Guide to Organization and Operation. New York: McGraw-Hill, 1977.

time instructor would be added in the second year. (See Appendix G for sample costing calculations.)

Competency. The department head should have a strong academic grounding in nuclear technology (BS degree in nuclear engineering or science, or equivalent) and suitable experience in industry (e.g., 2 years or more as operator trainee or operator). An instructor must have sufficient grounding in the technology (such as might be received from a well-organized tech school course), work experience or service in the nuclear Navy.

Availability. Qualified personnel must be available within a suitable time frame. (Assistance in identifying faculty requirements and in locating qualified personnel may be obtained from the local industrial advisory committee).

Affordability. The salary structure is a prime consideration. Instructors with experience in the nuclear industry command salaries competitive with industry. An institution must be prepared to pay more for nuclear technology instructors than for welding or mechanic instructors – perhaps even more than some of the deans or campus managers.

Technical programs are designed to produce supportive employees who increase the effectiveness of the total workforce. This principle should be applied to increase the effectiveness of the teaching staff.

Adequate time should be set aside to allow new staff personnel to review the curriculum materials, to visit – if possible – a successful program and its faculty, and to engage in a brief teacher training or familiarization program. The latter program should be designed to ensure that the teacher has an adequate overview of the curriculum materials and a general appreciation of the modular concept. Also, if possible, the teacher should be afforded an opportunity to dialogue with developers of the material, thereby resolving any variances between intended meaning and interpretation.

Staff assistants may be used in stock control to set out the proper equipment for laboratory classes, to keep equipment operating properly, to assist in the development of teaching materials, supervise laboratories, and do a limited amount of routine paper grading and project checking.

By adjusting the size of the supportive staff to the demands of enrollment, a school may partially solve the problem of staffing instructors when it is necessary to teach a number of different courses in one term. Supportive staff members may be recruited from the student body or from graduates of the program.

New approaches to the organization of faculty should be considered. Team teaching is one possible approach. In this sense, team teaching is the organization of a technical staff into a coordinated teaching unit. Teaching assignments are made on the basis of the individual member's special training and talents. Team planning allows for concurrent courses to be closely coordinated by team members to best utilize the student's time while the student is moved smoothly to progressively higher levels.

A weekly departmental staff meeting to encourage and sustain team teaching efforts is recommended. At these meetings, team members can assess and evaluate progress and plan on the basis of this evaluation and on current developments. This is especially important when a new course or a new technique is involved.

In addition to coordinating concurrent courses, staff meetings provide for free exchange of ideas on teaching techniques discovered to be useful and on recently developed laboratory projects which seem to be particularly successful.

To help keep a staff effective, an in-

stitution should encourage all staff members to up-date their knowledge of current industrial practice. Their knowledge of teaching techniques and innovations in education must continue to grow and expand. Membership in professional and educational associations should be encouraged, together with active participation in professional association work at local, state, regional and national levels. Through such organizations, faculty can keep up with new literature in the field and maintain closer liaison with employers.

Close contact with employers will also ensure success of the program through the following areas:

- Employment of graduates.
- Opportunities for cooperative programs.
- Assistance in organizing and presenting short courses and conferences.
- Donations of equipment and scholarships.
- A viable industrial advisory committee.

STUDENT SELECTION AND SERVICES

Preparing functionally competent nuclear reactor (plant) operator trainees makes three major demands upon the training program: 1) the training should equip graduates to take an entry job in which they will be productive; 2) it should enable graduates to advance to positions of increasing responsibility after a reasonable amount of experience; and 3) it should provide a comprehensive foundation to support further study.

Students entering the program should have certain capabilities, including comprehension and knowledge of underlying subject areas and related skills and adequate study habits and language competencies.

The Nuclear Regulatory Commission's requirements (for licensing reactor operators) influence employers of operator trainees; for example, no trainee is apt to be employed who cannot meet minimum health requirements established by the Commission. Similarly, emotionally unstable individuals and habitual users of drugs and alcohol, are generally considered not to be sufficiently reliable for the demanding responsibilities of nuclear reactor operation.

The program described in this Guide is designed for the typical average student (high school graduate or equivalent with one year of math and one basic science course); however, ability levels of those who enter the program generally vary greatly. Many students, whose intelligence and interest make them capable of mastering the curriculum required in the program, have under-developed scholastic skills. If applicants for admission to the program do not have the necessary scholastic background and skills, they should be given an opportunity to enter an organized program for the development of prerequisite skills before entering the technical program. This would ensure them a good probability of successfully completing the technical program. The institution should provide developmental programs to give students this opportunity.

Personal interviews with prospective students for the purpose of effective guidance and counseling are essential. Students should be given interest and aptitude tests by the guidance and counseling departments of the institution to assist them in selecting educational and occupational objectives consistent with their interests and abilities. This will assist them in determining their career objectives and selecting the programs appropriate to their interests.

Students should be given a thorough orientation program upon entry to the institution. This program should include an orientation to the facilities available on the campus, including the student lounges,

dining areas, bookstores and recreational facilities. In particular, they should be given a comprehensive tour of the library to familiarize them with its various facilities and procedures and rules governing its use.

Students should be provided information regarding student membership in technical and professional organizations, locally, statewide, and nationally, and encouraged to join such organizations. Membership in professional organizations provides students with an opportunity to receive excellent material on a regular basis at a substantial reduction in cost, to associate with other people in the field at meetings and to develop a habit of regularly reading journal articles to keep their technical knowledge in the field current.

Graduates of the program should be aided in every way in finding suitable employment. Placement of graduates is an important and multifaceted responsibility involving the placement department, the department head and instructors, and, either directly or indirectly, the advisory committee. However, the primary placement responsibility in new and changing technologies should rest upon the department faculty. They should send out announcements of upcoming graduates to the respondents of the needs survey and to committee members. Outstanding and successfully placed graduates and their employers are the most effective advertisers of the program.

The institution should conduct periodic follow-up studies of graduates to improve curriculum and teaching techniques, evaluate training effectiveness, maintain good employer-employee relationships, and provide a continuing evaluation of the total program.

FACILITIES

Industrial training programs vary widely according to need – from classrooms in a plant to sophisticated, specialized training centers; therefore, this discussion applies more specifically to institutional planners whose needs may be standardized to some extent.

For institutions, facility requirements of approximately 2000 square feet include the usual classroom(s), laboratory(ies), storage area(s), and staff office(s). Whenever possible, these areas should be combined in a single building for efficiency, economics and safety.

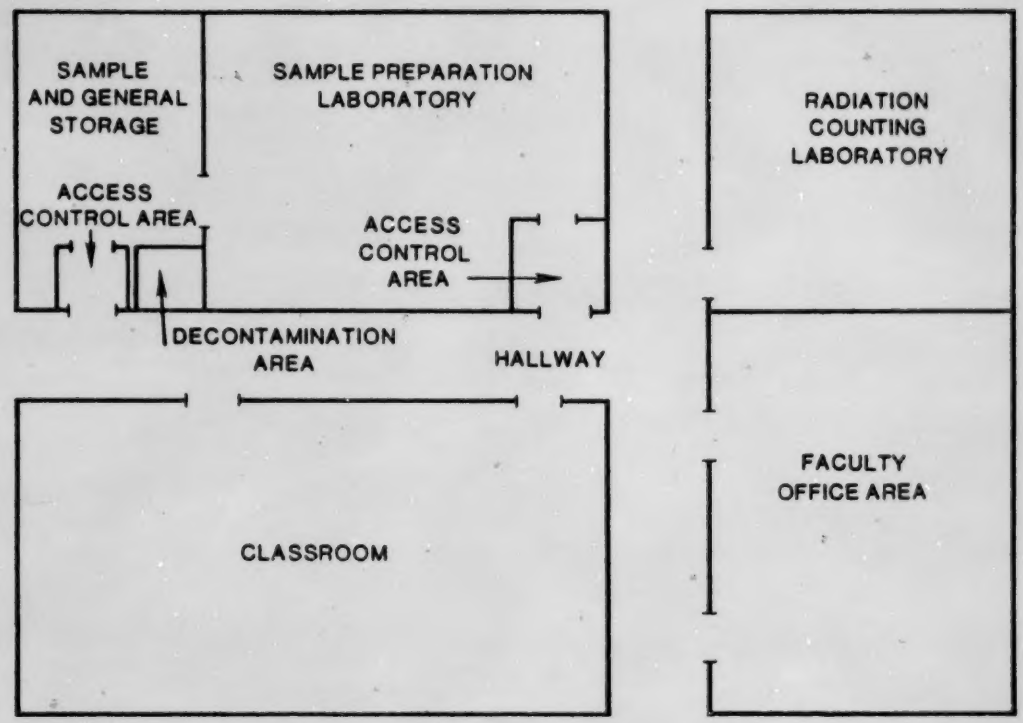
The following discussion assumes a class size of twenty-four students with two lab sections for each class. Thus, the classroom illustrated accommodates twenty-four to thirty students comfortably. The storage space included is adequate for audio-visual equipment and other materials normally required for classroom instruction.

A typical laboratory layout (page 24) for implementation of the complete curriculum would include all the elements shown; however, options offered as adjuncts to existing programs may adapt nuclear equipment to electronics or physics laboratories.

Two laboratories should be considered: 1) a general nuclear laboratory with radiation counting capabilities and 2) a sample preparation laboratory; it is necessary to keep counting instruments free from contamination by liquid samples.

General laboratory stations should provide ample table area for radiation counting equipment and work space for students' notebooks and charts. Ventilation is important.

Sample preparation laboratory stations should be designed for handling and storing radionuclides and small radioactive sources in a workbench-type layout. Counter tops and sinks (with hot and cold water taps) should be of stainless steel or chrome for easy decontamination and cleaning. Storage drawers should be leadlined. And key-locks should



SUGGESTED FACILITIES FLOOR PLAN

be installed to minimize unauthorized access.

A storage area adjacent to the sample preparation laboratory should include an accountability area for the storage of radioactive materials and contaminants. (Note: A system of accountability provides students with realistic, on-the-job type procedures.) Also, in this area, there should be a workbench and central tool storage.

Staff office space differentiates between department head and instructor(s), and places one person in each office to allow for personalized counseling.

Though new facilities may normally be acquired through established appropriation channels, some schools qualify for various special State and Federal grants. These should be explored by each school's grants department or personnel.

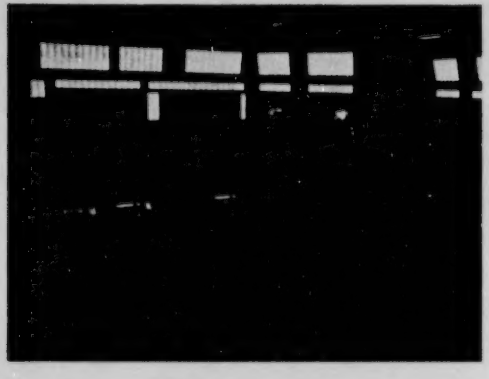
EQUIPMENT

Proper training of operators and technicians for industry entails hands-on experience with industrial-type equipment, insofar as is practical. All unique items of equipment necessary for a viable program in nuclear reactor operator training are listed

in Appendix E. This list incorporates specific items called out in each module and includes special nuclear laboratory storage and handling equipment.

Each item of equipment is accompanied by a recommended quantity, based on requirements of one class of twenty-four students divided into two laboratory sections of twelve students each. Cost approximations, based on 1979 vendor catalog prices, follow each listing.

The equipment list (Appendix E) includes unique items identified by authors of the curriculum materials as necessary or desired equipment for carrying out procedures included in the modules. (Note: Equipment should be equivalent to that used in industry whenever possible.) Ordering information is included with the equipment list.



Equipment in a sophisticated simulator control room.

Not included in the list are such items as visual and audio aids, models and simulators. Such materials are available commercially and from industry public relations offices. Simulators may be designed and built, for limited use, at a cost of a few thousand dollars or purchased at costs ranging from hundreds of thousands up to five million dollars and more. Usually, access to a research reactor (for institutional training) or a working reactor (for industrial training) can be arranged to permit familiarity with such equipment. A list of university research reactors is found in Appendix D. Also, used equipment and materials can provide excellent teaching aids. In industry-sponsored training programs, such equipment may be obtained from stock; institutions may need to look to industry – especially their industrial advisory committees – for contributions of used equipment.

LIBRARY

In each module, a list of reference materials is included. For the convenience of each institutional or industrial program developed, a suggested list of references and periodicals is presented in Appendix F.

Dynamic developments, causing rapid changes in technological science and practice, make it imperative that a student learn to use a library. Instruction for technology students should include assignments that require them to use the library so that they may form the habit of using the library as a tool in learning. This knowledge helps students develop professional attitudes and further teaches them to depend on libraries to keep abreast of new developments.

Reference materials and related media materials for teaching the technology should be reviewed continuously and revised or replaced, keeping in mind 1) the rapid development of new knowledge, techniques and procedures in the field, 2) the results of research in methodology of teaching in the field of nuclear technology, and 3) the dynamics of change within the structure and philosophy of nuclear industry. It is mandatory

that instructors constantly seek and review new references and related media materials as they become available and adopt those that are an improvement over those suggested in this Guide (Appendix F), or those currently in use.

Instructors of all courses should inform their students that library use is an important part of the program. Planned assignments that require the use of a library to research additional facts and new techniques on pertinent subjects enable students to understand the resources available and their relation to technology. Open-book examinations that require use of a library provide excellent, objective experiences. Under the incentive of such examination and the pressure of time, students obtain clear understandings of their own competencies in library use.

The growth and success of a graduate technician depend largely on an ability to keep up with changes in the field.

Library content may be classified as basic encyclopedic and reference index material, reference books pertinent to nuclear technology, relevant periodicals and journals, and audio-visual aids.

Therefore, a central library, under the direction of a professional librarian, is important to the success of a technology program. Most instructors have private libraries in their offices from which they may select books of special interest to discuss in their personal conferences with students, thereby stimulating interest in related literature; however, a central library ensures acquisition and cataloging according to accepted library practices and provides systematic card files, which facilitate the location of reference materials. It also provides a controlled and orderly system for lending books to students, typical of a system they might encounter as employed technicians. Provisions for lending materials for out-of-library use should be systematic and efficient. Suitable study space should be provided students for use of references.

A limited library incorporating books referenced in the curriculum material, supplemented by appropriate specifications (e.g., 10CFR50, ASME Boiler and Pressure Vessel Code, etc.) and relevant trade journals, should be maintained in the instructional area.

COST

The information given in Appendix E affords curriculum planners adequate data for estimating equipment costs based on 1979 price however, once a tentative equipment list is developed, planners are urged to contact appropriate distributors (from their own associations or from the vendor list provided in Appendix E) and obtain definite price quotes.

Equipment is only one cost that should be predetermined. Facility cost includes the classroom, laboratories, offices and associated areas. It also includes furnishing utilities and maintenance. In most schools and industrial facilities, these items are determined on a pro-rata basis.

The cost of supplies – used in the offices as well as in the classroom and laboratories, including handouts, preprinted tests and visual aids – should be estimated as accurately as possible.

Faculty and staff costs are a significant item. The costs of field trips and faculty travel and participation in industrial advisory committee meetings, technical associations and their activities, and special seminars should be anticipated.

Making determinations of program costs becomes meaningful when decisions must be made as to 1) whether or not the program is affordable, 2) whether or not the program

will be cost effective and 3) whether or not to implement the program.

To provide the program developer with a rationale for developing cost data, sample calculations are presented in Appendix G. Sample Calculation No. 1 assumes a full class – ongoing program – having department head and a full-time instructor. Calculation No. 2 assumes a typical first-year start-up program; one instructor who also acts as the department head and a minimum number of students. These calculations must not be accepted as accurately reflecting a given situation, but only as guidelines from which a program planner may extract appropriate techniques. Note that all cost estimates (including faculty) attempt to reflect both appropriation and budgetary items (for schools).

The final calculation in Appendix G applies to industry only.

PROGRAM IMPLEMENTATION AND EVALUATION

The level of effort involved in implementing a new program of instruction may vary from one setting to another, but the essential elements remain fairly constant.

IMPLEMENTATION

Implementation includes:

- Identifying needs.
- Determining curriculum requirements.
- Preparing and presenting program proposal, obtaining approval.
- Selecting and preparing staff.
- Acquiring facilities and equipment.
- Enlisting students.

LOCAL/REGIONAL NEEDS ASSESSMENT/ANALYSIS

Determination of needs consists of three steps:

Identification of employers:
- (both present and potential).

Identification of jobs:
- Task inventory.
- Entry-level requirements.
- Employment projections.

Analysis of Needs:
- Benefits versus expenditures.

A listing of employers should be available to interested schools. Local identification of such employers can be achieved readily with the counsel of a well chosen industrial advisory committee, many of whom will be employers (or representatives of employing organizations) of nuclear operators and technicians.

With the assistance of the committee and local employers, the several aspects of job identification can be successfully completed in a relatively brief period of time. Usually, this step can be carried out by mail, utilizing properly prepared survey instruments, examples of which are presented in Appendix C.

Any new program should be self-justifying. The benefits should justify the cost. Factors entering into this analysis include:

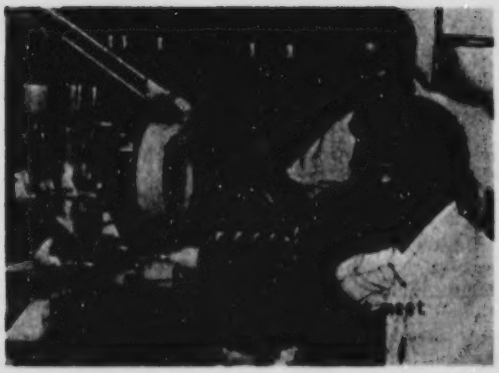
- Quantity of job opportunities.
- Quality of job opportunities.
- Projected job opportunities.
- Capability of institution to offer program:
  - Budget.
  - Facilities.
  - Faculty.
  - Administrative fervor.
    (Without an administrative commitment, no program is apt to evolve, even though all other elements are present.)

The industrial advisory committee's expertise should be utilized in this analysis of needs. Each member should be given an opportunity to review and evaluate the cumulative results of the needs survey and the school representative's assessment of the institution's capabilities. They may be able to suggest or propose ways of overcoming certain weaknesses or shortcomings.

CURRICULUM REQUIREMENTS DETERMINATION

Because curricula must be responsive (in technical education) to the real needs of technological industry, any determination of curriculum requirements must come after a realistic assessment and analysis of industrial workforce needs. The modular curriculum suggested in this Guide for training nuclear operators and technicians can be adopted wholly or in part to meet the real needs of industry. The materials to be used should be selected with care and, preferably, with the consultation of committee members to ensure compatability with industrial needs.

Personnel, familiar with the materials, content and sequencing and experienced in the matching of the curriculum to needs, should be utilized in developing the program. Members of the industrial advisory committee, with knowledge of workforce



training needs, should assist in the reviewing and selecting process.

Once program implementation reaches this development point, a formal proposal – in most institutions – must be prepared and presented to appropriate administrators, boards and agencies.

PROGRAM PROPOSAL PREPARATION

Three criteria should be satisfied in presenting a successful proposal for a new technical education program.

Need (for program). This criteria should have been established by the needs assessment and analysis. All data, both supportive and detractive, should be included along with letters or directly quoted comments and opinions of industrial advisory committee members.

Capability (of institution to provide program). This criteria includes: 1) fair and comprehensive evaluation of a school's interest in the program (top executives and/or administrative support and faculty enthusiasm), 2) its budgetary potential (requires a good estimate of program's cost and enrollment potential) and 3) its available facilities.

Cost effectiveness. There are two approaches to this determination: 1) immediate effectiveness – whenever possible, a program should be self-sustaining. Thus, it is important to establish program cost versus direct economic return. All the inputs that go into making this determination, including a realistic projection of enrollment in the program, should be incorporated into this proposal; 2) long-term effectiveness – total effect of the program on school resources should be weighed against benefits to society. In many instances, these determinants must be stated in intangible terms. Even so, they should be presented fairly and as accurately as possible.

PROPOSAL FORMAT

The format of the proposal varies extensively from school to school; however, as a general rule any proposal should be as straightforward, concise and simply stated as its preparer can make it. The following elements are meant only to imply a possible outline.

Preface. (What the document is; who prepared it; for whom was it prepared?) No more than one (1) page.

The Need. Reflecting all items discussed earlier.

The Curriculum.

The Plan. Organizational approach; facilities utilization; human and financial resources.

The Cost.

The Benefits.

The Recommendations. Based on reasonably drawn conclusions.

Lecters/documents of support.

Evaluation of existing compatible programs.

Once a program has received formal approval, instructional preparation becomes an immediate consideration.

EVALUATION

Human endeavor is subject to continual evaluation, generally informal, but evaluation nonetheless. It is this ongoing monitor-review activity that guides any individual or corporate activity to ultimate success - success that can only be assessed in retrospect. An educational program - human endeavor of a corporate nature - should also be evaluated progressively (as well as on the basis of its end product) to ensure its constancy toward the development of a successful end product.

CURRICULUM ACCEPTANCE

While a major evaluation factor is adequate enrollment, other criteria provide significant, if not major, evaluation tools:

Drawing power and holding power of program. Does program attract and hold qualified students in a manner comparable with similar technical programs?

Student enthusiasm and morale. Is there an observable esprit de corps within the classes or groups of students enrolled in the program?

Enrollment figures (compared with similar technical programs or with enrollment goals or limitations) answer the first question. The second may require a more comprehensive evaluation. For example, student response to a program may be evaluated subjectively by adjudging such factors as:

Interest/disinterest in classroom activities, laboratory procedures and homework or outside study (based on attentiveness and actions).

Enthusiasm/indifference as related to the total program (based on attendance).

Test scores on materials that judge student's progress in assimilating skills and knowledge essential for technical employment.

More commonly, however, evaluation tools are employed to reflect the students' responses more directly. This objective evaluation procedure (from the faculty's standpoint), which employs one or more questionnaires, seeks responses in the following areas:

Teacher effectiveness (including lab instructors).
Materials applicability (including understandability and program content relevance).
Facilities and equipment adequacy.
Student self-evaluation (including attitude, progress and continued interest.

GRADUATE PERFORMANCE

The ultimate evaluation of a technical education program stems from the success of its graduates:

Do their skills and knowledge meet entry-level requirements?
Are they successful in the job market?
Does their on-the-job performance satisfy employer expectations?
Are they promotable?

These questions may be asked of both the graduates and their employers. (Placement records may be more indicative of a hungry job market than a successful training program; therefore, evaluation should go beyond this initial transition from student to employee).

Graduated students, along with their employers, should also be asked to reflect upon or review the training program periodically. This means of relating program content to occupational needs should prove especially valuable in incorporating new or updating technological developments into the program.

APPENDICES

APPENDIX A

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APPENDIX B

TECHNICAL SPECIALTY COURSES AND MODULE TITLES AND DESCRIPTIONS

COURSE 1, RADIATION PHYSICS.

Module 1-1, "Introduction to Radiation Laboratory Safety."

This module examines basic radiation safety terms including: radioactivity, radiation, agreement state, monitoring radioactive waste and decontamination. Guidelines are also given which provide a method for developing specific laboratory rules relating to radiation safety.

Module 1-2, "Basic Radiation Detection and Measuring Equipment."

Included in this module is a description and discussion of the function of (a) ionization, (b) film badge, (c) dosimeter, (d) scaler, (e) ratemeter and (f) count-rate.

Module 1-3, "Atomic Structure and Radioactivity."

This module includes basic principles of atomic structure, definition of elements and atoms, and a description of the Geiger-Müeller plateau. Each topic is illustrated with labeled diagrams.

Module 1-4, "Radioactive Decay and Half-Life."

Radioactive decay and half-life are described through the definition of (a) radioactive decay, (b) stability, (c) nuclear force, (d) electrostatic force, (e) half-life, (f) decay constant, (g) activity, (h) specific activity, (i) Avogadro's number, (j) curie, (k) nucleon, (l) gram-atomic weight and (m) atomic weight.

Module 1-5, "Radioactive Decay Processes and Schemes."

Several aspects of particulate radiation are described including particle speed, mass in AMU, electrical charge and penetrability. Sample decay equations and decay schemes for given decay processes are illustrated. Instructions are also given for reading and interpreting the Chart of Nuclides.

Module 1-6, "Basic Properties of Gamma Radiation."

This module includes a basic description of gamma radiation and its properties.

COURSE 2, RADIATION PROTECTION I.

Module 2-1, "Radiation Exposure and Absorbed Dose Values."

This material involves a study of radiation exposure and absorbed dose values by defining the limits of usage for the units of radiation dosage, teaching rapid conversion from all systems of units into rem and explaining why quality factor is different for different types of radiation.

Module 2-2, "Biological Effects of Radiation."

The biological effects of radiation including: mechanisms by which radiation damages living body cells, typical radiation syndrome, differentiation between internal and external radiation exposures are presented. Also included is a discussion and evaluation of the hazards of biological injury to the general population versus that to the radiation worker and an explanation of the benefit versus risk concept in the use of radiation.

Module 2-3, "Radiation Protection Standards."

Initially this module examines the radiation protection standards associated with dose level exposures for accumulated whole body, extremities and skin. The correct completion of all application and report forms required by state and local standards pertinent to radiation protection and establishment and maintenance of record systems that facilitate compliance with the regulations are also included.

Module 2-4, "Internal Dose Calculations."

Various methods of internal dose calculation are discussed including: MPC, body burden, standard man, bioassay, ICRP, critical organ, handbook 69, effective half-life, empirical, smear, RBE, radiosensitivity, ash sample, one-shot intake.

Module 2-5, "Personnel Monitoring Devices, Ionization Types."

This module contains a detailed look at the ionizing type personnel monitoring devices. The two common types of dosimeters are illustrated, their structure examined, and the mechanism for charging and reading the dosimeter is discussed. The precautions and limitations to be observed in using dosimeters are also listed.

Module 2-6, "Personnel Monitoring Devices, Chemical Types."

Chemical types of personnel monitoring devices are looked at in detail. Five different types are examined as to their ability to detect ionizing and neutron radiation, basic operational feature, relative accuracy and speed of use. Guidelines are also provided for the selection of the most practical types to be utilized under given radiation monitoring situations.

COURSE 3, PRINCIPLES OF PROCESS INSTRUMENTATION.

Module 3-1, "Temperature-Sensing Devices: Glass-Bulb Thermometers."

The glass-bulb thermometer as a basic temperature sensing device is discussed as to its operational theory, variety and ability to monitor temperature.

Module 3-2, "Temperature-Sensing Devices: Thermocouples."

This module discusses in detail the operational theory of thermocouples and temperature measurement systems utilizing thermocouples.

Module 3-3, "Temperature-Sensing Devices: Resistance Thermometers."

A detailed presentation concerning the theory and operation of resistance thermometer systems is given.

Module 3-4, "Temperature-Sensing Devices: Pyrometers."

The temperature measuring qualities of an optical pyrometer are listed, and its design and optimum use are detailed.

Module 3-5, "Basic Principles of Flow Measurement."

This module studies the principles of flow and pressure and measurement of each using the proper instruments.

Module 3-6, "Pressure-Sensing Devices."

This module examines the operating characteristics and use of several manometer and mechanical gage type pressure-sensing devices. The devices are compared and contrasted and their optimum use described.

Module 3-7, "Flow-Sensing Devices: Differential Pressure Flowmeters."

The specific characteristics, applications, advantages and disadvantages, installation and maintenance of differential-pressure flow measurement devices are discussed. The terminology related to calibration of the devices is also covered.

Module 3-8, "Flow-Sensing Devices: Linear Flowmeters."

Basic operating principles of primary elements of linear flowmeters and related secondary elements are discussed. The specific characteristics, uses, advantages and disadvantages, installation, alignment (calibration), operation and maintenance are discussed for power plant applications.

COURSE 4, HEAT TRANSFER AND FLUID FLOW.

Module 4-1, "Basic Properties of Fluids."

This module gives a basic introduction to matter and its properties. The various temperature scales, measurement of density, specific weight, buoyancy and viscosity are some of the properties of fluids that are discussed. Energy movement is also discussed in the law of heat exchange, specific heat, heat of fusion and melting and vaporization.

Module 4-2, "Fluid Statics."

Several aspects of pressure related to fluids are illustrated and examples of related calculations given. The characteristics of force and pressure, pressure in liquids at rest, principles of hydraulics and pressure calculations on submerged bodies are also provided.

Module 4-3, "Fluid Dynamics."

The topic of fluid dynamics is examined through the discussion of the venturi meter, Bernoulli's principle and the Reynolds number. Other effects on fluid systems discussed include friction and other causes of pressure loss.

Module 4-4, "Heat Transfer by Conduction."

This module discusses the one of three methods of heat transfer, namely conductivity. Units used to describe heat transfer are defined as are specific heat, heat flux and atomic action. A tabular comparison of the conductivity of several materials is also presented.

Module 4-5, "Heat Transfer by Convection."

A second type of heat transfer by convection is described in detail. Natural and forced convection are discussed with details of calculating forced convection under given circumstances presented. The convection current patterns created by expanding fluids in a confined area are also described.

Module 4-6, "Heat Transfer by Radiation."

The phenomenon of thermal radiation as another mechanism of heat transfer is described. The electromagnetic radiation emitted by a body as a result of its temperature is calculated. Thermal conductivity of several building materials is listed and discussed. A comparison between a black body absorber and a white body emitter is described.

Module 4-7, "Change of Phase - Boiling."

This module gives a brief description of the states of matter and their inherent characteristics. Enthalpy and entropy as thermodynamic properties are also discussed. Included also are

calculations of the quality and void fraction properties of a liquid, and, finally, a description of five types of boiling are provided.

Module 4-8, "Burnout and Flow Instability."

The mechanisms for calculating critical flux, DNB and DNBR are described as well as detailed descriptions of how burnout and flow instability are detected in reactor systems.

Module 4-9, "Reactor Heat Transfer Limits."

Heat transfer limits are discussed by examining fuel rod design and characteristics, limiting design factors of the reactor and calculating critical heat flux given certain conditions. Power output is also described as it pertains to radial and axial power distribution, peaking factors and critical heat flux ratios.

COURSE 5, INTRODUCTION TO NUCLEAR SYSTEMS.

Module 5-1, "Basic Nuclear Reactor Components."

Sketches and diagrams are used to illustrate and discuss the components of a light water reactor, reactor vessels, control rod drive systems (PWR and BWR) and fuel assemblies in PWR and BWR systems.

Module 5-2, "Pressurized Water Reactor (PWR)."

This module gives a detailed look at a pressurized water reactor (PWR) including the hydraulic, pneumatic and electrical components. Diagrams and illustrations show their internal structures. and the two basic types of steam generators are illustrated and discussed.

Module 5-3, "Boiling Water Reactor (BWR)."

The boiling water reactor (BWR) is described in detail including its advantages and limitations. Illustrations clearly describe the various systems and components of the BWR. Fuel assemblies, control rods and jet pumps are also described in detail.

Module 5-4, "Primary Cooling Systems."

A brief review of the reactor vessel, pressurizers and steam generators is provided. Detailed mechanisms and design characteristics of reactor coolant pumps, piping, primary systems, valves and insulation is also shown. Overall design specifications and in-service inspection is also discussed.

Module 5-5, "Nuclear Instrumentation."

This module describes in detail the types and components of radiation detectors used to monitor radiation levels in power plants. Four kinds of radiation and associated instruments are listed and discussed as well as back up or fail safe systems for monitors.

Module 5-6, "Nuclear Fuel Cycle."

The complete nuclear fuel cycle is illustrated and described in detail through the following steps: (a) mining, (b) milling, (c) refining, (d) enriching, (e) oxide fabrication and (f) fuel assembly through reprocessing spent fuel. Plutonium and thorium are also introduced as potential fuels for the future. A visit to a plant involved in one of the steps in the cycle is encouraged.

COURSE 6, INSTRUMENTATION AND CONTROL OF REACTORS AND PLANT SYSTEMS.

Module 6-1, "Neutron Monitoring Systems."

Electrical output is measured as a function of neutron activity in power plants, consequently, the monitoring of the level of neutron activity is described in great detail. Definitions of source range, intermediate range and power range are given, and the monitoring techniques for each are examined.

Module 6-2, "Neutron Sensors."

The mechanics of operation of gas-filled neutron detectors is reviewed in this module. Also described and illustrated are a fission chamber, boron proportional counter, compensated ion chamber, uncompensated ion chamber and neutron thermopiles.

Module 6-3, "Neutron Flux Signal Conditioning."

This module examines electrical output characteristics of neutron detection devices and how preamp circuits are used to process the information prior to display. Methods of detector signal analysis and conditioning used to monitor nuclear flux are also presented.

Module 6-4, "Control-Rod Drives and Indicating Systems."

A key to the operation of a reactor is its mechanisms associated with the control rods which are explained in detail through discussions of nonsolid and solid control element systems, shapes and materials of control rods and the different methods of control-rod drives. The module also discusses the system most common to PWR and BWR applications.

Module 6-5, "Instrumentation Power Supplies."

Schematic diagrams of reactor power supplies are given in this module. Passive and active power supply filters are also described and illustrated.

Module 6-6, "Installation of Instrumentation Systems."

Several aspects of instrumentation installation are covered in this module including descriptions of the four categories of instrument systems, instrument system standards and components, installation steps and techniques and system inspection. A final discussion centers around quality assurance and quality control in reactor power plants.

COURSE 7, REACTOR OPERATIONS.

Module 7-1, "Reactor Operator Licenses."

This module describes in detail the licensing process for reactor operators which includes these steps: (a) authority to issue, (b) exceptions to requirement, (c) applications for examination, (d) approval criteria, (e) written and operating tests (senior operator requirements as well), (f) waiver of examination, (g) exam prior to criticality, (h) appeal procedures, (i) license issuance, (j) renewal and (k) requalification program.

Module 7-2, "Administrative Control for Nuclear Systems."

A brief historical sketch of nuclear regulations is presented followed by the step-by-step licensing process from construction permit, safety reports, environmental impact statements, license revocation, to a general utility organization pattern.

Module 7-3, "Reactor Operating Experiences."

A series of case studies of typical, unusual incidents at nuclear reactors (including power plants) that resulted in scram or violation of technical specifications is presented, along with genesis operating problems.

Module 7-4, "Reactor Startup Procedures."

A typical reactor pre-operational and startup program is described for a boiling water reactor (considered typical of all light-water reactors).

Module 7-5, "Pressurized Water Reactor Operating Characteristics."

Each system (nuclear, hydraulic, thermal, pneumatic and electrical) and its interrelationships with other systems is described and illustrated. The module also details operating parameter, fail safe systems, shut down and start up procedures and requirements.

Module 7-6, "Boiling Water Reactor Operating Characteristics."

The basic operating mechanisms of a BWR are discussed and illustrated. Included in the discussion are: (a) nuclear steam supply systems, (b) control rod assemblies, (c) fuel bundles, (d) balance of the plant, (e) reactor power control and (f) loss-of-coolant accidents.

Module 7-7, "Refueling of Reactors."

A step-by-step refueling procedure is described which includes these points: (a) fuel arrival, (b) shutdown procedures, (c) refueling equipment, (d) refueling cycles for both BWR and PWR power plants, (e) equipment inspection repair and (f) power refueling inspection. The procedure for handling the spent fuel is also described.

COURSE 8, REACTOR SAFETY.

Module 8-1, "Introduction to Reactor Safety."

Five major points are covered in this module including: (a) reactor safety philosophy (design safety, multiple barriers and redundant safety systems), (b) implementation of safety programs, (c) reactor site selection criteria, (d) classification and evaluation of possible accidents and (e) a summary of the Rasmussen study.

Module 8-2, "Reactor Licensing."

Historical sketches and influence of the following organizations is discussed: (a) AEC, (b) NRC, (c) Federal Register Code and (d) level of state authority. NRC licensing procedure, safety analysis report, environmental impact interpretation, and operators' licenses are also reviewed.

Module 8-3, "Reactor Protection Systems."

This module emphasizes eight categories of characteristic design parameters for protective devices and systems. Also included are discussions of the philosophy and design basis, specific system design, standards and regulations, examples of plant variables, operational aspects of protection systems and applications of protection systems.

Module 8-4, "Reactor Emergency Systems."

Logic diagrams and illustrations of reactor shutdown systems and emergency core cooling systems in BWR and PWR power plants are detailed in this module. Other topics covered include: (a) purpose of reactor emergency systems, (b) radiation monitoring systems, (c) nuclear instru-

mentation systems, (d) emergency power systems, (e) fire protection systems and (f) other emergency systems.

Module 8-5, "Safeguards and Security."

The question of security related to nuclear proliferation and industrial sabotage are initially introduced followed by a breakdown of the responsibilities and mechanisms for security in the (a) owner controlled area, (b) protected area and (c) vital area. Employee selection and design of the security plan are discussed. Finally, a look at the security related to the entire fuel cycle is described from the mine to the reprocessor.

COURSE 9, REACTOR AUXILIARY SYSTEMS.

Module 9-1, "Containment and Ventilation of Reactors."

Schematic diagrams of PWR and BWR containment buildings are detailed. The basis of design conditions, design basis accidents, construction access and penetrations, heat removal, ventilation, monitoring of containment ventilation and post accident removal of H_2 is also discussed.

Module 9-2, "Spent Nuclear Fuel Storage and Handling Procedures."

This module follows these steps in the handling of spent nuclear fuel: (a) fuel handling systems, (b) reactor cavity and refueling canal, (c) main fuel handling bridge, (d) fuel storage handling bridge, (e) fuel transfer system (f) equipment to reduce fuel handling time, (g) refuel transfer methods and systems, (h) refueling procedure and schedule and (i) health physics procedures.

Module 9-3, "Emergency Power Systems for Reactors."

Emergency power for inplant operation is presented in a unique schematical plan, with component by component descriptions as well as overall concept discussion.

Module 9-4, "Residual and Emergency Cooling Systems for Reactors."

A detailed description including a comparison and contrast between BWR and PWR coolant systems is given. The interaction of the coolant under startup, normal operating and emergency conditions is summarized.

COURSE 10, POWER PLANT SYSTEMS.

Module 10-1, "Power Plant Fundamentals."

This module explains the physical and mathematical properties of using heat energy to transfer water to steam. The process is looked at in a closed boiling system and an overview is given of the process in BWR and PWR power plants.

Module 10-2, "Power Plant Thermal Cycles."

The emphasis in this module is on the basic laws and processes governing thermal cycles in power plants. Brief discussions are also provided for (a) energy and work, (b) forms of energy, (c) review of BWR and PWR steam systems, (d) thermodynamic cycles and (e) heat balance.

Module 10-3, "Turbines and Generators."

The major classifications of turbines, construction features, generator types and components, general operating and maintenance are described in this module. Applicable auxiliary equipment and systems are also introduced.

Module 10-4, "Heat Exchangers and Condensers."

Heat exchange is the basis upon which a power plant operates; therefore, the various aspects of (a) shell-and-tube heat exchangers, (b) U-tube steam generators, (c) once-through steam generators, (d) main condensers, (e) feedwater heaters, (f) cooling towers and (g) spray ponds are illustrated and discussed.

Module 10-5, "Pumps."

Over one hundred pumps can be found in a modern steam power plant. Three major types are illustrated and discussed; their parts, characteristics, and function are also described in detail.

Module 10-6, "Valves and Piping."

This module presents a detailed illustrated discussion of valve types, components, flow characteristics, operation, safety requirements and types of actuators. Descriptions of pipes and fittings used include their sizes, schedules, safety classes, hangers, materials and expansion joints.

Module 10-7, "Electrical Transmission and Distribution Systems."

Principles of transmission and distribution are discussed, and systems and equipment are described, along with typical operating problems and solutions.

Module 10-8, "Power Plant Fundamentals (Fossil Fuel Energy Efficiency)."

An overview is given of the basic types of fossil fuels used to power electric generating plants. Emphasis is placed on plant efficiencies to measure effective fuel use.

Module 10-9, "Fossil Plant: Auxiliary Discussions."

Characteristics and basic operating procedures of fossil fuel plants are described in this module including five boiler designs, classification of fuels, heating values of each, and a discussion of combustion reaction in a boiler. The module also defines economizer, superheater, reheater, blowdown, vapor separators, supercritical, and petroleum and gaseous fuels.

COURSE 11, RADIATION DETECTION AND MEASUREMENT.

Module 11-1, "Statistics of Radiation Counting."

Radioactivity follows certain predictable patterns which are statistically described through the definitions of (a) radioactive decay, (b) geometry factor, (c) interactions, (d) inverse-square law, (e) dead time, (f) average value, (g) standard error, (h) theoretical standard deviation (i) standard deviation and (j) normal distribution. Background radiation and changes in counter geometry are also discussed.

Module 11-2, "Gas-Filled Detectors I: Ionization Detectors."

Three types of ionization detectors including the integrating, nonintegrating and mean-level are described. The module also describes the calculation of current produced by given exposure, ionization chambers and curves, and the details of a pocket dosimeter. Other terms defined in the module include: (a) pulse counter, (b) ion pair, (c) recombination, (d) saturation voltage, (e) saturation current, (f) discriminator, (g) air equivalence, (h) energy dependence, (i) spectroscopy and (j) efficiency.

Module 11-3, "Gas-Filled Detectors II: Proportional Counters."

This is the second module in a series discussing detectors and describes proportional counters –

the five basic types and varieties. Definitions found in the module include: (a) P-10 gas, (b) internal proportional counter, (c) 4π or absolute counter, (d) flow-through counter, (e) discriminator, (f) resolving time, (g) fission counter, (h) proton recoil counter, (i) Hurst counter and (j) Hurst dosimeter.

Module 11-4, "Gas-Filled Detectors III: Geiger-Müeller Counters."

This is the third module in the detector series and specifically describes the operating mechanisms of a gas-filled detector using the Geiger counter as an example. Terms discussed and defined include: (a) internal and external quenching, (b) limited proportionality, (c) breakdown voltage, (d) continuous-discharge region, (e) multiple discharge, (f) dead time, (g) recovery time, (h) geometry factor and (i) self-absorption.

Module 11-5, "Scintillators, Semiconductors and Spectroscopy."

Another class of detectors includes the solid-state devices discussed in this module including the four basic types of scintillation counters and the three categories of semiconductor devices. Also covered are such terms as: (a) photomultiplier tube, (b) luminescence, (c) phosphorescence, (d) activator, (e) photocathode, (f) dynodes, (g) secondary emission ratio, (h) well crystal, (i) p-n junction, (j) depletion layer, (k) GeLi detector and (l) pulse-height analysis.

Module 11-6, "External Personnel Dosimeters for Beta-Photon Monitoring."

Two major types of dosimeters (namely, photographic and luminescent dosimeters) are discussed and illustrated including the mechanisms for calibration, limitations, and optimum use. Several other items are described including: (a) roentgen, (b) rad, (c) rem, (d) quality factor, (e) latent image, (f) sensitivity, (g) energy dependence, (h) radiophotoluminescence, (i) thermoluminescence, (j) glow curve and (k) glow peak. The effect of radiation dose is also briefly discussed.

Module 11-7, "Neutron Detectors, Dosimetry and Activation Analysis."

Three major groupings of neutron detectors and their applications are described and the details of a compensated ionization chamber, activation foils, the albedo neutron dosimeter and a fission-fragment dosimeter are included. Neutron activation analysis is also introduced and briefly described.

Module 11-8, "Radiological Calibration and Standardization."

This module examines five aspects of radioactive standardization including: (a) measurement of disintegration rate, (b) mass determination, (c) calorimeter, (d) source preparation and (e) standardized solutions used. Common radioactive standardization sources are discussed and requirements of the National Bureau of Standards also are outlined.

COURSE 12, REACTOR PHYSICS.

Module 12-1, "Neutron Physics."

Five major topics are covered in this module starting with an identification of neutron sources followed by a description of the classification of neutrons, neutron flux and fluence, neutron detection and finally neutron survey meters.

Module 12-2, "Cross Sections and Reactions."

Many neutron interactions are possible during the fission process, and the possibilities and probabilities through the concept of cross section are described. The application and methods of

measurement of cross section are also listed. Introduction to the basic laboratory procedures demonstrating absorption, attenuation, thermalization and activation is also provided.

Module 12-3, "Fission Rate and Reactor Power."

The discovery of the process of fission is described in this module followed by discussions of thermal neutrons, fission fragments, fission neutrons, origins of fission energy and spontaneous fission. Several terms introduced in the module include: (a) transuranium elements, (b) fissile, (c) fertile materials, (d) fission yield, (e) unsymmetrical yield, (f) decay heating and (g) spontaneous fission.

Module 12-4, "Time Independent Nuclear Theory."

Subcritical, critical and supercritical reactor conditions are defined as well as a description of neutron flux, four and six factor formulas, subcritical multiplication and critical mass. The following list of terms is also used in the explanation of these concepts: (a) neutron generation, (b) multiplication factor, (c) thermal neutron, (d) fast neutron, (e) resonance region, (f) fissile material and (g) fissionable material.

Module 12-5, "Time Dependent Nuclear Theory."

The time dependent nature of a reactor is examined in this module through kinetics and neutron flux, and by describing the activities of prompt and delayed neutrons and the in-hour equation.

Module 12-6, "Reactivity – Fuel Moderator and Control Systems."

An interrelationship exists between three critical components of a reactor, namely the fuel, control-rod system and moderator which is described in detail. Their effect on the total reactivity of the plant is examined. Sound fuel management is also presented; and these key ideas are supported by the definition of core excess, heavy and light water, SCRAM, megawatt day, burnable poison and chemical shim.

Module 12-7, "Internal Effects on Reactivity."

This module examines the three basic factors – temperature, fission products and voids – which affect the final reactivity of a reactor proper. Reactivity coefficients are also defined and their effect on overall activity of the reactor is described.

Module 12-8, "Reactor Operating Characteristics."

The three basic reactor types including the PWR's, BWR's and GCR's are described as to their specific operating characteristics. Schematics are shown and summaries given of the number and types of reactors found in operation in the world.

COURSE 13, POWER PLANT CHEMISTRY.

Module 13-1, "Water Quality Control."

Three basic topics are covered in this module starting with sources of water and initial treatment, to specific preparation of reactor makeup water and finally the equipment used to monitor its quality. Several of the impurities and their potential effect on the function of the system are also given in detail.

Module 13-2, "Raw Water Treatement."

The five most common water contaminants including color, suspended and dissolved solids, gases,

odors and algae are discussed and the methods of treatment (coagulation, filtration, chlorination and de-aeration) are described.

Module 13-3, "Sources of Impurities in Reactor Water Systems."

An initial look at the consequences of scale formation is provided in this module. Common forms of metal corrosion and sources of reactor impurities including metal corrosion, activation products and fission products are described.

Module 13-4, "Water Treatment – Polishing by Ion Exchange, Evaporation and Demineralization."

Water treatment processes such as ion exchange and demineralization are explained both in theory and actual process during this module. Types most commonly used in PWR's and BWR's are identified and illustrated.

Module 13-5, "Water Properties Sensing."

Specific examples of devices used to monitor pH, conductivity, dissolved oxygen, halide ions and turbidity are presented in this module, and their location in the primary and condensate feedwater systems of PWR's and BWR's is described.

Module 13-6, "Water Analysis for Nuclear Power Plants."

This module examines the various water sampling techniques that are not of a continuous nature but are used to monitor less critical impurities. Frequency of these tests, methods and instruments used to establish their level and their significance in the reactor system are also defined.

Module 13-7, "Radioactive Waste Handling – Liquid and Gaseous."

The sources of gaseous and liquid wastes in BWR's and PWR's and the treatment of these wastes is covered in detail. Summary of the Federal Regulations concerning the disposal of radioactive gases, liquids and solids is also reviewed.

COURSE 14, INTRODUCTION TO QUALITY ASSURANCE/QUALITY CONTROL.

Module 14-1, "Basic Requirements for Quality Assurance/Quality Control in the Nuclear Industry."

This module introduces the topic of QA/QC through a description of: (a) Federal regulatory processes, (b) an overview of QA/QC, (c) other participants in the licensing process, (d) the impact of technical professional organizations on QA/QC and (e) a listing of the self-regulating mechanisms of the industry.

Module 14-2, "Definitions and Descriptions of Quality Assurance/Quality Control Criteria."

A concise definition of quality assurance and quality control and their differences are given in this module. The meanings of each of the eighteen QA criteria and basic duties of QA/QC personnel are also provided.

Module 14-3, "Governmental Regulation of Quality Assurance/Quality Control (AEC, NRC)."

The historical evolution of the AEC and NRC and their impact on nuclear regulation includes a discussion of Federal Regulation 10CFR50. Also included in this module is a description of the NRC rainbow-colored books which discuss various aspects of QA/QC. Finally, a brief description of the NRC regulatory guides is provided.

Module 14-4, "Technical Regulation of Quality Assurance/Quality Control (ASME, ANSI)."

Section III of the ASME code is examined in detail as is ANSI standard N45-2. The influence of ASTM, IEEE, ACI and AWS on QA/QC is also given.

Module 14-5, "Implementation of Quality Assurance/Quality Control Programs and Procedures."

The parts of the QA/QC manual are described including minimum standards. A method of devising procedures and instruction documents and the contents of the ten parts is also provided. Finally, a note as to the functions of the QA/QC personnel is documented.

Module 14-6, "Application of Quality Assurance/Quality Control to Industry."

This module specifies the five requirements of 10CFR50, ASME code and ANSI standards for quality assurance/quality control which affect: (a) design aspects of materials, components and facilities, (b) manufacturing processes, (c) construction, testing and inspection and (d) operation and maintenance for nuclear facilities.

Module 14-7, "Techniques and Variations in Quality Assurance/Quality Control."

Three QA/QC establishment procedures are described including user developed, consultant assisted and subcontracted programs. Example forms are provided as indicators of typical tag sheets for QA/QC monitoring.

Module 14-8, "Quality Assurance/Quality Control Records and Documents."

Verification of QA/QC activities is handled through accurate, timely documentation of forms shown in this module. Selection of mechanisms for indexing, storage and retrieval of permanent and nonpermanent records through the record control center is also discussed.

Module 14-9, "Special Studies in Quality Assurance/Quality Control."

General QA/QC requirements for technical and quality-assurance specifications are described. Several aspects of QA/QC personnel including: (a) certification, (b) on-the-job training and (c) seminars, indoctrination programs, and orientations are also outlined. Briefly identified also are six methods of inspections, tests and verifications.

COURSE 15, METALLURGY AND METALS PROPERTIES.

Module 15-1, "Fabrication Processes for Metals."

A basic introduction is given in the fabrication processes for steel from its creation from pig iron to the structural changes resulting from shaping and heat treating. Various tube steel products are also listed.

Module 15-2, "Chemical Analysis of Metals."

This module examines impurities in ferrous metals of primary containment systems which must meet ASME boiler and pressure vessel code requirements. ASTM standards, carbon analysis and emission spectroscopy are also related to the analysis of metal impurities.

Module 15-3, "Basic Metallurgical Concepts."

Several steps are taken to form alloys including the processes of solidification, phases of matter, properties of a solid solution and solid-liquid equilibrium characteristics — all of which are described in this module.

Module 15-4, "Properties of Steel."

Glossary terms needed to understand the hardening properties of steel alloys are listed in this module. The uses of the various steel alloys in power plants are also identified.

Module 15-5, "Metallographic Examination."

Examining metal alloys is done using the unaided eye and the optical reflecting microscope. Preparation of test specimens using proper laboratory procedures to examine the grain structure is also outlined.

Module 15-6, "Mechanical Testing — Tensile, Bend, Hardness."

This module applies the properties of metal testing through three basic tests, namely: (a) tensile, (b) bend and (c) hardness. The operation of these tests and the interpretation of the test results is also presented. Many of the tests are illustrated and practice exercises allow the application of principles.

Module 15-7, "Mechanical Testing — Impact, Nick Break, Fatigue."

Three mechanical tests of metals including the single blow "impact" test, multiple flexures in the "bend" test and frequently repeated stress applied in the "fatigue" test are illustrated, described and the resultant metal changes are discussed.

Module 15-8, "Failure Mechanisms in Metals."

The various causes of metal failure with an emphasis on the interaction of various types of radiation with different classes of material are detailed in this module.

COURSE 16, MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS.

Module 16-1, "Pump Characteristics and Specifications."

The description, function, characteristics and various types of pumps needed in a reactor are identified in this module. Various pressure-flow characteristics are also presented.

Module 16-2, "Piping Characteristics and Specifications."

This module examines the various materials used in pipes, their specifications, functions, joining methods, inspection schedules and types of expansion joints commonly used.

Module 16-3, "Valve Characteristics and Specifications."

Several types of valves used in power plants including their description, specifications, operation mechanisms are illustrated and discussed in this module.

Module 16-4, "Fastener Characteristics and Specifications."

Common types of fasteners used, especially nuts and bolts, studs of various materials, and thread standards form the text for this module.

Module 16-5, "Lifting and Handling Equipment Characteristics and Specifications."

Basic handling equipment such as cranes, hoists and conveyors are described and illustrated. Characteristics, specifications and limitations are also listed.

Module 16-6, "Rotating Equipment Characteristics and Specifications."

This module examines all types of rotating equipment such as motors, blowers, generators and turbines (but not pumps) and lists specifications, functions and general descriptions of each.

Module 16-7, "Heat Exchanger Characteristics and Specifications."

The common types of heat exchangers, their function, description and specifications, including materials and thermal/hydraulic characteristics, are provided in this module.

Module 16-8, "Pressure Vessel Characteristics and Specifications."

Pressure vessel function, description and specification such as materials, types and thermal/hydraulic characteristics are outlined and discussed in this module.

Courses being developed for the other curricula in the Nuclear Technology series (see chart on Page 12) follow:

COURSE 17: RADIATION PROTECTION II.

Module 17-1: Film Dosimetry.
Module 17-2: Thermoluminescent Dosimetry (TLD).
Module 17-3: Radiation Dose Assessment – Personnel Dosimeters.
Module 17-4: Bioassay Techniques (Internal Dose Assessment).
Module 17-5: Record Keeping for Radiation Protection.

COURSE 18: RADIOLOGICAL EMERGENCIES.

Module 18-1: General Procedures for Radiological Emergencies.
Module 18-2: Emergency Equipment for Nuclear Facilities.
Module 18-3: Surface Contamination – Decontamination.
Module 18-4: Criticality Control.
Module 18-5: Control of Radiological Hazards.
Module 18-6: Emergency Planning for Nuclear Facilities.
Module 18-7: Emergency Drills for Nuclear Facilities.

COURSE 19: RADIATION SHIELDING.

Module 19-1: General Effect of Radiation Attenuation.
Module 19-2: Beta and Alpha Particle Attenuation.
Module 19-3: Neutron Attenuation.
Module 19-4: Gamma Attenuation.
Module 19-5: Background Radiation Reduction Techniques.
Module 19-6: Backscattering and Wall Scattering of Radiation.

COURSE 20: RADIATION MONITORING TECHNIQUES (RADIOCHEMICAL).

Module 20-1: Radiation Sample Preparation – Liquid.
Module 20-2: Radiation Sample Preparation – Solid.
Module 20-3: Air Monitoring Techniques – Particulate.
Module 20-4: Air Monitoring Techniques – Gaseous.
Module 20-5: Water Monitoring Techniques – Dissolved Solids.
Module 20-6: Water Monitoring Techniques – Suspended Solids.
Module 20-7: Radiation Monitoring of Biological Samples.

COURSE 21: RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT.

Module 21-1: Waste Disposal Procedures. (Same as Module 25-6.)
Module 21-2: Routine Sampling of Radioactive Waste.
Module 21-3: Waste Disposal Regulations.
Module 21-4: Measurement of External Radioactive Contamination. (Same as Module 25-8.)
Module 21-5: Regulations for Transporting Radioactive Materials.
Module 21-6: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 25-7.)
Module 21-7: Leak Tests of Sealed Radioactive Sources.

COURSE 22: ADVANCED RADIONUCLIDE ANALYSIS.

Module 22-1: Survey of Methods Used in Radionuclide Analysis (Sample Collection & Analysis).
Module 22-2: Gamma Spectrometry.
Module 22-3: Alpha Spectrometry.
Module 22-4: Beta Spectrometry.
Module 22-5: Radiochemical Methods of Analysis by Liquid Scintillation Counting.
Module 22-6: Neutron Activation Analysis.
Module 22-7: Determination of Specific Nuclides (In the Environment).

COURSE 23: NUCLEAR CHEMICAL PROCESSES.

Module 23-1: Head-End Treatment.
Module 23-2: Ion Exchange.
Module 23-3: Solvent Extraction.
Module 23-4: Precipitation Techniques and Centrifugation.
Module 23-5: Techniques of Chemical Concentration.
Module 23-6: Diffusion and Enrichment Process.
Module 23-7: Nuclear Waste Handling Processes.

COURSE 24: NUCLEAR SYSTEMS AND SAFETY.

Module 24-1: Neutron Physics. (Same as Module 12-1.)
Module 24-2: Cross Sections and Reactions. (Same as Module 12-2.)
Module 24-3: Fission Rate and Reactor Power. (Same as Module 12-3.)
Module 24-4: Nuclear Criticality.
Module 24-5: Nuclear Material Inventory Management Techniques.
Module 24-6: Nuclear Plant Safeguards.

COURSE 25: RADIOACTIVE MATERIAL HANDLING TECHNIQUES.

Module 25-1: Glove Box Operations – Fundamentals.
Module 25-2: Glove Box Operations – Advanced.
Module 25-3: Master/Slave Manipulator – Fundamentals.
Module 25-4: Master/Slave Manipulator – Advanced.
Module 25-5: Remote Sampling Techniques.
Module 25-6: Waste Disposal Procedures. (Same as Module 21-1.)
Module 25-7: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 21-6.)
Module 25-8: Measurement of External Radiation Contamination. (Same as Module 21-4.)

COURSE 26: NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I.

Module 26-1: Visual tests.
Module 26-2: Leak Tests.
Module 26-3: Hydrostatic Tests.
Module 26-4: Liquid Penetrant.
Module 26-5: Fundamentals of Radiography.
Module 26-6: Radiograph Inspection.
Module 26-7: Radiographic Specifications and Code Requirements.

COURSE 27: METROLOGY.

Module 27-1: Fundamentals of Metrology.
Module 27-2: Fixed Gages, Dividers, Calipers and Micrometers.
Module 27-3: Gage Blocks, Mechanical Comparators and Electronic Comparators.
Module 27-4: Angle-Measurement Instruments, Optical Projectors and Surface Texture Gages.
Module 27-5: Tolerancing.
Module 27-6: Calibration.
Module 27-7: Statistical Techniques in Metrology.
Module 27-8: The Total Measurement System.

COURSE 28: WELDING INSPECTION.

Module 28-1: Welding Fundamentals and Processes.
Module 28-2: Shielded Metal Arc and Oxyacetylene Welding.
Module 28-3: Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding.
Module 28-4: Weld Joint Verification.
Module 28-5: Qualifications.
Module 28-6 Process Controls.
Module 28-7: Acceptance Inspection.
Module 28-8: Filler Material Control.
Module 28-9: Weld Repair Control.
Module 28-10: Records.

COURSE 29: CIVIL/STRUCTURAL INSPECTION.

Module 29-1: Inspection of Construction Operations.
Module 29-2: Structural Steel Materials, Installation and Inspection.
Module 29-3: Concrete Materials.
Module 29-4: Concrete Preparation, Production, Placement and Finishing.
Module 29-5: Concrete Testing and Inspection.
Module 29-6: Prestressed Concrete Materials, Fabrication and Inspection.

COURSE 30: MECHANICAL INSPECTION.

Module 30-1: Pump Inspection.
Module 30-2: Pump Functional Testing.
Module 30-3: Valve Inspection.
Module 30-4: Piping Inspection.
Module 30-5: Surface Cleaning Inspection.
Module 30-6: Protective Coating Inspection.
Module 30-7: Pressure Vessel Inspection.
Module 30-8: Rotating Equipment Inspection.

COURSE 31: QUALITY-ASSURANCE PRACTICES.

Module 31-1: Overall Quality Assurance Program.
Module 31-2: Vendor Qualification.
Module 31-3: Receiving Inspection.
Module 31-4: Identification, Storage and Handling of Components, Parts and Materials.
Module 31-5: Nonconforming Material.
Module 31-6: Certification and Qualification of Quality-Control Inspectors.
Module 31-7: Auditing for Quality Assurance.
Module 31-8: Document Handling, Storage and Retrieval for Quality Assurance.

COURSE 32: NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES II.

Module 32-1: Fundamentals of Ultrasonic Testing.
Module 32-2: Operation of Ultrasonic Test Equipment.
Module 32-3: Fundamentals of Magnetic Particle Testing.
Module 32-4: Operation of Magnetic Particle Test Equipment.
Module 32-5: Fundamentals of Eddy Current Testing.
Module 32-6: Operation of Eddy Current Test Equipment.

COURSE 33: CONTROL SYSTEMS I.

Module 33-1: Introduction to Block Diagrams.
Module 33-2: Input/Output Devices.
Module 33-3: Control System Theory.
Module 33-4: Pneumatic Control Mechanisms.
Module 33-5: Control Valves.
Module 33-6: Process Control Characteristics.

COURSE 34: CONTROL SYSTEMS II.

Module 34-1: Introduction to Transfer Functions.
Module 34-2: Frequency Response Analysis.
Module 34-3: Combination Control Systems.
Module 34-4: Controller Tuning.
Module 34-5: Operational Amplifiers.
Module 34-6: Microprocessor Utilization.
Module 34-7: Microprocessor Programming.

COURSE 35: POWER PLANT ELETRICAL SYSTEMS AND COMPONENTS.

Module 35-1: Electrical Distribution.
Module 35-2: Instrumentation and Control for Major Plant Components.
Module 35-3: Recording and Display Devices.
Module 35-4: Process Control Loops and Devices.
Module 35-5: Cathode-Ray Tube Systems (CRT).
Module 35-6: Preventative Maintenance for Systems and Components.
Module 35-7: Instrument Reliability.

APPENDIX C

SUGGESTED WORKFORCE NEEDS SURVEY INSTRUMENT FOR NUCLEAR TECHNICIAN AND REACTOR TRAINEES

Dear Sir:

I am writing to ask for your help. Our school is considering the establishment of a 2-year technical program in the new field of nuclear power plant operation. Prior to establishing such a program, I have been asked to conduct a survey of the present and future needs in this locale for technicians with this special training. I have enclosed the survey, which should take just a few minutes to complete. When you are done, simply place this survey in the enclosed stamped addressed envelope and return. If you wish a copy of the results of the survey, please so indicate at the end of the questionnaire.

If, for some reason, this questionnaire does not apply to your specific area of responsibility at your organization, please pass it on to someone to whom it may be more appropriate.

I appreciate your efforts in behalf of this new occupational training program in the state.

Sincerely,

_____
Title

TYPICAL WORKFORCE NEEDS SURVEY INSTRUMENT FOR NUCLEAR TECHNICIAN AND REACTOR OPERATOR TRAINEES

Name of company, institution, or government division:

_____

_____

Definitions: Nuclear Reactor (Power Plant) Operator – A person responsible for proper daily routine and emergency operation of nuclear reactor or nuclear power plant.

Trainee – As a trainee the person is gaining the the information and experience to properly operate the reactor (or plant) and preparing to be examined for licensing by the Nuclear Regulatory Commission.

	Yes	No	
1.	_____	_____	Does your company currently employ people who are licensed or are under training for licensing as Nuclear Reactor Operators?
2.	_____	_____	Do you have current vacancies for Nuclear Reactor Operators and trainees?

3. Please indicate the typical beginning salary a Nuclear Reactor Operator Trainee might expect to receive in your company.

a. $700-800/mo. _____		d. $1201-1400/mo. _____	
b. $801-1000/mo. _____		e. $1401-1600/mo. _____	
c. $1001-1200/mo. _____		f. Greater than $1600/mo. _____	

4. In your opinion, your need for Nuclear Reactor Operator Trainees during the next ten years will:

_____ decrease	_____ increase by 26-50%
_____ remain the same	_____ increase by 51-75%
_____ increase by 0-25%	_____ increase by 76-100% or more

5. Can you give an estimate of the total number of Nuclear Reactor Operator Trainees you will need in the next five year period?

1980	_____	1983	_____
1981	_____	1984	_____
1982	_____		

6. As you employ Nuclear Reactor Operator Trainees in the future would you:

_____ prefer to train these individuals yourself?

_____ prefer to hire individuals trained in nuclear plant fundamentals in a recognized and approved institution?

7. Please circle those items in which you think the Nuclear Reactor Operator Trainee should receive specific training:

I. Fundamentals of reactor theory.
   - A. Fission process.
   - B. Energy release.
   - C. Neutron multiplication.
   - D. Source effects.
   - E. Control-rod effects.
   - F. Criticality indications.

II. Design features of core.

III. Mechanical design features of the reactor system.

IV. General operating characteristics.
   - A. Causes and effects of temperature.
   - B. Pressure and reactivity changes.
   - C. Effects of load changes.
   - D. Operating limitations and reasons for them.

V. Design, components and functions of reactivity control mechanisms and instrumentation.

VI. Design, components and functions of safety systems.
   - A. Instrumentation.
   - B. Signals.
   - C. Interlocks.
   - D. Automatic and manual features.

VII. Components, capacity and function of reserve and emergency systems.

VIII. Shielding, isolation and containment procedures for the facility/plant (specific).

IX. Balance of plant – turbines, condensers, pumps, valves, piping, heat exchangers, generators, and auxiliary equipment.

X. Other – Please list.

8. Due to specific duties, titles for a Nuclear Reactor Operator may vary; which of the following titles are used by your company to describe these individuals?

_____ Test Reactor Operator.
_____ Research Reactor Operator.
_____ Nuclear Power Plant Operator.
_____ Watch Engineer.
_____ Auxiliary Equipment Operator.
_____ Unit Operator.
_____ Reactor Irradiation Servicing Technician.
_____ Control Operator.
_____ Senior Control Operator.
_____ Shift Foreman.
_____ Shift Engineer.
_____ Licensed Reactor Operator.
_____ Licensed Senior Reactor Operator.
_____ Simulator Instructor.
_____ Fuel Handling Technician.

9. Please indicate the type and manufacturer of reactor your company operates:

_____ Boiling Water Reactor.
_____ Pressurized Water Reactor.
_____ Research Reactor.
_____ Other _____;

10. Would you classify your company's principal endeavor as:

_____ Electrical power production.
_____ Research and development.
_____ Nuclear materials processing and disposal.
_____ Equipment manufacturer.
_____ University or private training consultant.
_____ Other (specify) _____.

11. Comments: Please include any additional information which you feel would help us identify the need in numbers and competencies for Nuclear Reactor Operators.

_____

_____

_____

_____

	Yes	No	
12.	_____	_____	Would you like to receive a copy of the report summarizing the results of this survey?

Please mail to: _____

_____

_____

_____

Your kind assistance in completing this survey questionnaire is appreciated.

APPENDIX D

UNIVERSITIES WITH RESEARCH REACTORS

Brigham Young University (L-77)
California State Polytechnic College (AGN-201)
Catholic University (AGN-101)
Columbia University (TRIGA)
Cornell University – Zero Power Reactor (ZPR)
Cornell University (TRIGA)
Massachusetts Institute of Technology (CP-5)
Michigan State University (TRIGA)
North Carolina State University (Polstar)
Ohio State University
Oregon State University (TRIGA)
Penn State University (TRIGA core)
Purdue University
Reed College (TRIGA)
Rhode Island (AEC)
State University of New York (PULSTAR)
Stanford University
Texas A & M (TRIGA)
Texas A & M (AGN-201M)
Tuskegee Institute (AGN-201)
University of Arizona (TRIGA)
University of California at Irvine (TRIGA)
University of California at Los Angeles (Argonaut)
University of California at Santa Barbara (L-77)
University of Delaware (AGN-201)
University of Florida (Argonaut)
University of Illinois (TRIGA)
University of Illinois (LPRA)
University of Kansas
Georgia Institute of Technology (CP-5)
Idaho State University (AGN-201)
Iowa State University
Kansas State University (TRIGA)
University of Lowell
Manhattan College
University of Maryland (TRIGA)
University of Michigan
University of Missouri at Rolla
University of Missouri at Columbia
University of New Mexico (AGN-201)
University of Oklahoma (AGN-201)
University of Texas (TRIGA)
University of Utah (AGN-201)
University of Virginia (Pool)
University of Virginia (Cavalier)
University of Washington
West Virginia University
University of Wisconsin (TRIGA core)
Virginia Polytechnic Institute
Washington State University (TRIGA core)
Worcester Polytechnic Institute
Memphis State University (AGN-201)

APPENDIX E

EQUIPMENT LIST WITH COST, QUANTITY AND VENDOR DATA

COURSE	TYPE OF EQUIPMENT	1979 UNIT COST	QUANTITY REQUIRED	TOTAL COST
	Radiation:			
1	Alarm monitor, 1 per entrance to radiation area	$ 413	1	$ 413
12	Analyzer, multi-channel pulse height	7,500	1	7,500
1;12	Chart of the Nuclides	3	1	3
1	Coats, white knee-length lab (disposable)	3	48	144
6	Compensated ion chamber	500	1	500
6	Uncompensated ion chamber	500	1	500
	Decontamination kit with radiation signs and labels, ropes, cleaner, drum, brushes	150	1	150
11	Densitometer	563	1	563
	Developing tank, 2 gallon stainless steel	75	2	150
1	Dosimeters, direct reading pocket	63	48	3,024
1	Dosimeter charger	88	5	440
11	Dosimetry film, commercial personnel monitor film (Type NTA and Type 3)	63	1 box of each	126
1;11	Dosimeter, thermoluminescent (TLD),			
	Annealed Calibration source	500	1	500
	Holder	5	72	360
	Muffle furnace	250	1	250
	Reader	4,000	1	4,000
	TLD chips TLD 100 (LiF)	5	240	1,200
	Tweezers	5	24	120
11	Electrometer	288	1	288
1	Film badge	10	assortment/ 3 types	10
11;12	GeLi detector, with shielding and liquid nitrogen coolant	40,000	1	40,000
1	Gloves, disposable rubber or plastic	10/100	100 pr.	10
2	Ionization counters (2π), gas flow type	750	12	9,000
11	NaI (Tl) crystals	75	12	900
6	Neutron detector	163	1	163
6	Neutron source (obtainable from DOE for cost of shipping)			
1;2;5;11;12	Radioactive sources in exempt quantities	313	assortment	313
2	Ratemeters, ion chamber type	500	12	6,000
1;5;11;12	Scaler-ratemeters, Geiger-Mueller	1,500	12	18,000
1;11	G-M probes, end window	88	12	1,056
1	G-M probes, side window	75	12	900
1	G-M tubes for G-M probes	113	12	1,356
1	Shoe covers	5	12 pr.	60
1	Storage container for rad waste	325	1	325
11	Survey meter, ionization chamber (Cutie Pie)	663	1	663
5;6;12	Survey meter, neutron with BF_3 detector	250	1	250
1;11	Survey meters, portable (from various distributors)	313	12	3,756
	Work bench modules			
	Decay cabinet	1,000	12	12,000
	Sink and waste	1,625	12	19,500
	Storage	2,750	12	33,000
	Electrical:			
10	Generator, AC	113	1	113
3	Decade resistance box (5 place)	100	1	100
13	Electrodes, glass and reference	10/set	12 sets	120
3;13	Millivoltmeters (0-50 mv)	163	12	1,956
1;6	Oscilloscope, cathode-ray	1,000	1	1,000
3,15	Potentiometer, dial type with built-in standard cell	500	1	500

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF EQUIPMENT	1979 UNIT COST	QUANTITY REQUIRED	TOTAL COST
6	Voltage regulator	$ 125	1	125
3	Voltmeter, 3.5 digit (0-50 mv)	88	12	1,056
	Mechanical:			
15	Analyzer, Leco 50-second carbon (pulse-height)	1,000	1	1,000
3	Barometer, mercury	100	1	100
4	Calorimeter	7	1	7
5;13	Centrifugal pump, approximately 30 gpm	375	1	375
13	Conductivity meter and cell	750	1	750
15	Emery papers, miscellaneous grades no. 0 through 000	15	12 sets	180
13	Extensometer, tensile test	6,250	1	6,250
3;10;15	Flowmeter, with adapters for variable area, rotating, turbine	250	1	250
3;4	Gages			
	Hydraulic press and pressure	75	1	75
	Instrument-air			
	High volume	750	1	750
	Low volume	750	1	750
	Pressure	63	2	126
4	Hydrometers			
	All-purpose	7	1	7
	Commercial	6	1	6
15	Induction furnace	313	1	313
3;10	Manometer, 30" U-tube	63	2	126
15	Molder for metal specimen preparation, plastic	75	1	75
13	Nitrogen tank	75	1	75
3;4	Oriface plates	5	3	15
13;15	Oxygen tank	75	1	75
4	Pascal's vases, metallic diaphragm	225	1	225
15	Polishes, cerium oxide and tin oxide	42	1 lb/each	42
15	Polishing lap	17	1	17
15	Polishing machine, vibratory	530	1	530
4	Pycnometer	17	1	17
3	Rotameter	200	1	200
4;12;13;15	Samples of iron, aluminum, copper, low carbon steel, medium carbon steel, high carbon steel, cast iron, alloy steel, chromium steel	5	1/each	45
10	Shaft eccentricity detector	25	1	25
10	Shaft vibration measuring instrument	38	1	38
10	Steam turbine, small	100	1	100
3;15	Testing machines	BORROW FROM ANOTHER TECHNOLOGY		
	Brinell hardness testing machine			
	Dead weight tester (12-500 psi range)			
	Impact test machine			
	Rockwell hardness testing machine			
	Tensile testing machine			
	Vickers hardness testing machine			
3	Venturi tube	10	1	10
	Chemical:			
13	Cartridge filter, 3/4" P.T. fittings	38	1	38
	Filter housing, 3/4" P.T. fittings	50	1	50
13	Demonstration kit:	188	1	188
	6 amberlite ion-exchange resin tubes, model #334, Mallinckrodt Chemical Works, St. Louis, MO (or equivalent)			
13	pH buffer solutions	15/set	1 set	15
13	pH indicator strips	30/10 pkg	1	30
13	pH meter	375	1	375

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF EQUIPMENT	1979 UNIT COST	QUANTITY REQUIRED	TOTAL COST
	Dimensional:			
15	Calipers, vernier	$ 15	12	$ 180
15	Dividers, fine point	8	12	96
	Meter stick	4	1	4
1	Yardstick	4	1	4
	Hardware:			
3;4;10	Pipe and assorted fittings, galvanized	25/50 ft	1	25
13	Signal cable	10/100 ft	1	10
3;4;13	Tubing			
	Glass	80/25 lb	1	80
13	Koroseal	10/100 ft	1	10
	Rubber	30/50 ft	1	30
3;5;10	Valves			
	Air vent, butterfly, check, diaphragm, gate, globe, motor (or pneumatic, actuated, plug, Y-pattern, 3-way, 4-way, needle	100	1 asst.	100
	Temperature Measurement:			
3	Resistance Temperature Detector (RTD) open wire element, 100	625	1	625
3	Resistance Temperature Detector (RTD) standard platinum, 100 (-20°C to 200° range)	620	1	620
3	Temperature recorder	630	1	630
15	Thermocouples	10	24	240
3;4;13	Thermometers			
	General laboratory	5/30	assortment	150
	NBS thermometer (traceable -10 to 100°C secondary standard, total immersion type)	400	1	400
	Test thermometers, identical to NBS	100	12	1,200
3	Wire			
	Copper lead	250/250 ft	1	250
	Thermocouple, iron-constantan	125/50 ft	1	125
	Auxiliary:			
1	Absorbers, aluminum and lead	113	set of 12	113
13;15	Balance, analytical	475	1	475
4	Balance, triple beam	100	1	100
3,13	Beakers, graduated with spouts, assorted sizes	125	12 sets	1,500
13	Burets, assortment of sizes	7	24	168
3	Collection tank, calibrated (weighing tank)	40	1	40
	Centrifuge	400	1	400
	Desiccator	63	1	63
4	Discs or rods, lithium flouride	200	assortment	200
15	Files, flat/fine, 1" x 6"	3	12	36
11	Filters, low Z	7	36	252
3,13	Flasks			
	Dewar flask with holder	12	1	12
	Erlenmeyer flasks with rubber stoppers	120/10 sets	1	120
1;3	Holders for samples	70	12	840
3;4	Hot plate with motorized stirrer	140	1	140
4	Jars, hydrometer	5	asst. of 30	150
	Lamps, heat	25	12	300
15	Microscope, reflecting, light, metallurgical	5,000	1	5,000
13	Pipettes, assorted sizes	100/10 sets	1	100
1;3;13	Ring stands to support G-M probes	20	12	240
11	Sleeves, paraffin, polyethylene, cadmium			
2;3;4	Stopwatch	40	1	40
3	Telescope, 10x magnification and mount	200	1	200
1	Timers, if not integral to the scaler-ratemeter	100	12	1,200
3	Tubes, test, assorted sizes	100/10 sets	1	100

Estimated equipment costs based on 1979 prices.

For courses requiring film badge service for continuous recording of radiation, a cost of $45.00 for 20 badges should be allowed for each quarter.

PARTIAL LIST OF EQUIPMENT SOURCES

VENDORS

The following list indicates companies that provide catalogs or information used in the preparation of this Guide. It is not a comprehensive list, and no endorsement of these companies or their equipment is intended or implied.

ALPHA DIVISION
Ventron Corporation
P. O. Box 299
152 Andover Street
Danvers, MA 01923

ATOMIC PRODUCTS CORPORATION
Atomlab Division
P. O. Box 657
Center Moriches, NY 11934

CENTRAL SCIENTIFIC COMPANY
2600 South Kostner Avenue
Chicago, IL 60623

CURTIN MATHESON SCIENTIFIC, INC.
A Coulter Subsidiary Company
CMS International Division
P. O. Box 1546
4220 Jefferson Avenue
Houston, TX 77001

DEFENSE APPAREL-NUCON PRODUCTS
P. O. Box 14703
163 Murphy Road
Hartford, CT 06114

THE EALING CORPORATION
22 Pleasant Street
South Natick, MA 01760

FISHER EDUCATIONAL MATERIALS DIVISION
4901 West Lemoyne Avenue
Chicago, IL 60651

THE HARSHAW CHEMICAL CO.
Crystal and Electronic Products Department
6801 Cochran Road
Solon, OH 44139

JORDAN NUCLEAR COMPANY
3244 Arroyo Seco Avenue
Los Angeles, CA 90065

R. S. LANDAUER, JR. & CO.
Glenwood Science Park
Glenwood, IL 60425

LUDLUM MEASUREMENTS, INC.
501 Oak Street
Sweetwater, TX 79556

NUCLEAR ASSOCIATES, INC.
Radiation-Medical Products Corporation
100 Voice Road
Carle Place, NY 11514

VICTOREEN, INC.
10101 Woodland Avenue
Cleveland, OH 44104

SARGENT-WELCH SCIENTIFIC CO.
7300 North Linder Avenue
Skokoe, IL 60076

TECH/OPS RADIATION PRODUCTS DIVISION
Northwest Industrial Park
Burlington, MA 01803

U.S. DEPARTMENT OF ENERGY (DOE)
(Formerly ERDA) Surplus Equipment List
See Catalog of Federal Domestic Assistance, available from the Superintendent of Documents, Washington, DC 20402

APPENDIX F

SUGGESTED LIBRARY REFERENCES AND MATERIALS

BOOKS

American Nuclear Society. Nuclear Power and the Environment: Questions and Answers. Hinsdale, IL: ANS, 1976.

Atomic Energy Legislation through the 92nd Congress, 2nd Session. Joint Committee on Atomic Energy, 1973: U.S. Government Printing Office. This document contains all legislation from 1946 through 1973.

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USAEC. "The Safety of Nuclear Power Reactors (Light Water Cooled) and Related Facilities." USAEC Report WASH-1250, 1973.

USNRC. Code of Federal Regulations, Title 10. U.S. Government Printing Office. This document is updated and reissued every year. Supplements are issued through the year by NRC.

U.S. Nuclear Regulatory Commission Guides. Available from the Director of Regulatory Standards, USNRC, Washington, D.C.

Veillon, Claude. "Atomic Absorption." In Atomic Absorption Spectroscopy – Instruments. M. Dekker, ed. 1972.

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JOURNALS (NUCLEAR)

ATOMIC DATA AND NUCLEAR DATA TABLES
Academic Press, Inc.
111 Fifth Avenue
New York, NY 10003

ATOMIC ENERGY CLEARINGHOUSE
Congressional Information Bureau, Inc.
Colorado Bldg. 14th & G Streets N.W.
Washington, DC 20005

ENERGY
Business Communications Co.
471 Glenbrook Rd.
Stamford, CT 06906

ENERGY DEVELOPMENTS
International Review Service
15 Washington Place
New York, NY 10003

ENERGY REPORTER
Federal Energy Administration
Old Post Office Bldg., Room 3076
Washington, DC 20461

HANFORD NEWS
Department of Energy
Atlantic Richfield Hanford Co.
P. O. Box 250
Richland, WA 99352

HEALTH PHYSICS JOURNAL
4720 Montgomery Lane
Suite 506
Bethesda, MD 20014

INIS ATOMINDEX
UNIPUB
P. O. Box 433
Murray Hill Station
New York, NY 10016

INSTITUTION OF NUCLEAR ENGINEERS JOURNAL
(Formerly NUCLEAR ENERGY)
Institute of Nuclear Engineers
1 Penerley Rd.
London SE6 2LQ, England

NUCLEAR INDUSTRY STATUS
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR INFO
Atomic Industrial Forum
475 Park Avenue South
New York, NY 10016

NUCLEAR INSTRUMENTS AND METHODS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

NUCLEAR MATERIALS MANAGEMENT
Institute of Nuclear Materials Management
Seaton Hall
18 Seaton Hall
Manhattan, KS 66506

NUCLEAR NEWS
American Nuclear Society
244-a, E. Ogden Avenue
Hinsdale, IL 60521

NUCLEAR POWERPLANT PERFORMANCE
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR SAFETY
U.S. Nuclear Regulatory Commission Publication
Superintendent of Documents
Government Printing Office
Washington, DC 20402

NUCLEAR STANDARDS NEWS
American Nuclear Society
244 E. Ogden Avenue
Hinsdale, Il 60521

JOURNAL OF NUCLEAR MATERIALS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

JOURNAL OF NUCLEAR SCIENCE AND TECHNOLOGY
Atomic Energy Society of Japan
c/o Japan Atomic Energy Research Institute
1-13 Shimbashi, Minato-Ku
Tokyo, Japan

JOURNAL OF PHYSICS: NUCLEAR PHYSICS
Institute of Physics
47 Belgrave Square
London SWIX 8QX, England

NUCLEAR FUEL STATUS AND FORECAST
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR TECHNOLOGY
American Nuclear Society, Inc.
244 E. Ogden Avenue
Hinsdale, IL 60521

NUCLEONICS WEEK
McGraw-Hill, Inc.
1221 Avenue of Americas
New York NY 10020

OAK RIDGE ASSOCIATED UNIVERSITIES NEWSLETTER
Oak Ridge Associated Universities, Inc.
Information Services Dept.
Box 117
Oak Ridge, TN 37830

OAK RIDGE NATIONAL LABORATORY REVIEW
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830

AGENCIES, ASSOCIATIONS, AND SOCIETIES

Additional relevant reference materials may be obtained directly from the following sources.

AGENCIES

International Atomic Energy Agency (IAEA)

IAEA Proceedings and Directory available for purchase from its Division of Publications.

International Commission on Radiation Units and Measurements (ICRU)

International Commission of Radiological Protections (ICRP)

National Council on Radiation Protection and Measurements (NCRP)

United Nations Scientific Committee on the Effects of Atomic Radiation

United States Government

Department of Energy
Nuclear Regulatory Commission

All NRC/DOE documents are available for purchase from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151

ASSOCIATIONS AND SOCIETIES

American Concrete Institute (ACI)

American National Standards Institute (ANSI Standards)

American Nuclear Society (ANS)

American Society of Mechanical Engineers (ASME)

AMSE Boiler and Pressure Vessel Code

American Society of Quality Control (ASQC)

American Society for Testing Materials (ASTM)

American Welding Society (AWS)

Atomic Industrial Forum (AIF)

Institute of Electrical and Electronic Engineers (IEEE)

AUDIO-VISUAL AIDS

In addition to aids used by the instructor(s), there are available films and other pertinent materials showing research or production that should be available to students of nuclear technology on a selective basis. Frequently these items can be made available by equipment vendors, utility companies, Government agencies and other organizations that may be represented on a program's industrial advisory committee.

Babcock and Wilcox
Manager, Special Products and Service Marketing
Nuclear Power Generation Division
Lynchburg, VA 24505

General Electric Company
Manager – BWR Training
Mail Code 594
175 Curtner Avenue
San Jose, CA 95125

DOE – Technical Information Center
Oak Ridge National Laboratory
P. O. Box 62
Oak Ridge, TN 37830

U.S. Department of Health, Education and Welfare
Public Health Service
Bureau of Radiological Health
Rockville, MD 20852

American Society of Mechanical Engineers
Education Division
345 East 47th Street
New York, NY 10017

American Nuclear Society
555 North Kensington Avenue
La Grange Park, IL 60525

APPENDIX G
SAMPLE COSTING CALCULATIONS

SAMPLE CALCULATION NO. 1

(Two faculty members and full enrollment of students)

Assumptions:
- 24 1st-yr students.
- 16 2nd-yr students.
- 14 grads annually after 2nd yr.
- 1 Dept. head @ $24,000 - 1st yr salary.
- 1 Instructor (beginning 2nd yr) @ $18,000 - 1st yr salary.
- 1/2 Secretary @ $8,000 - 1st yr salary.
- Benefits and overhead equal to 50% of annual salaries.
- Facility modifications cost of $31,250.
- Initial capital equipment cost of $88,500 (for 1st-yr courses only).
- Additional capital equipment cost of $113,500 for 2nd-yr courses.
- Annual expendables cost of $13,000 for both 1st- and 2nd-yr courses.
- Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 31,250.00		
	Equipment	88,500.00		
			$ 119,750.00	
1st-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Benefits & Overhead	14,000.00		
	Expendables	6,500.00		
	Misc.	2,500.00	51,000.00	
			$ 170,750.00	$ 170,750.00
2nd-yr equipment expenditures			$ 113,500.00	
2nd-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Instructor	18,000.00		
	Benefits & Overhead	23,000.00		
	Expendables	13,000.00		
	Misc.	5,000.00	87,000.00	
			$ 200,500.00	$ 200,500.00
				$ 371,250.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 28,000	$ 47,400	$ 49,770	$ 52,260	$ 54,870
Benefits & Overhead	14,000	23,700	24,885	26,130	27,435
Equipment	10,000	25,750	25,750	25,750	25,750
Facilities	6,250	6,250	6,250	6,250	6,250
Expendables	6,500	6,500	6,500	6,500	6,500
Miscellaneous	2,500	5,000	5,000	5,000	5,000
Annual Totals	$ 67,250	$114,600	$118,155	$121,890	$125,805

*5% annual salary increase included.

SAMPLE CALCULATION NO. 2

(One faculty member and minimum enrollment.)

Assumptions:
12 1st-yr students.
8 2nd-yr students.
6 grads annually after 2nd yr.
1 Dept. head/instructor @ $20,000 - 1st-yr salary.
1/2 Secretary @ $7,000 - 1st-yr salary.
Benefits and Overhead equal to 40% of annual salaries.
Facility modification cost of $6,000.
Initial capital equipment cost of $45,000 (for 1st-yr courses only).
Additional capital equipment cost of $65,000 for 2nd-yr courses.
Annual expendables cost of $6,500 for both 1st- and 2nd-yr courses.
Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 6,000.00		
	Equipment	45,000.00		
			$ 51,000.00	
1st-yr expenditures	Dept. head	$ 20,000.00		
	Secretary	3,500.00		
	Benefits and Overhead	9,400.00		
	Expendables	3,000.00		
	Misc.	5,000.00		
			40,900.00	
			$ 91,900.00	$ 91,900.00
2nd-yr equipment expenditures			$ 65,000.00	
2nd-yr expenditures	Dept. head	$ 21,000.00		
	Secretary	3,700.00		
	Benefits and Overhead	12,350.00		
	Expendables	6,500.00		
	Misc.	5,000.00		
			48,550.00	
			$ 113,550.00	$113,550.00
				$205,450.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 23,500	$ 24,700	$ 25,935	$ 27,237	$ 28,593
Benefits and Overhead	9,400	9,880	10,374	10,892	11,437
Equipment	11,000	25,000	25,000	25,000	25,000
Facilities	1,200	1,200	1,200	1,200	1,200
Expendables	3,200	6,500	6,500	6,500	6,500
Miscellaneous	2,000	5,000	5,000	5,000	5,000
Annual Totals	$ 50,300	$ 72,280	$ 74,009	$ 75,823	$ 77,730

*5% annual salary increase included.

SAMPLE CALCULATION NO. 3

(Industrial Training Facility)

Assumptions: Facility diversion: $60,000
Equipment diversion: $55,000
On-staff instructor(s) - annual salary $28,000.
1/2 Secretary - annual salary $9,000.
Benefits and Overhead - 50% of annual salaries.
Annual expendables cost of $1,200/student.
Miscellaneous cost of $300/student.
10 students/yr.

Calculation:

1st-yr expenditures		
	Facility	$ 60,000.00
	Equipment	55,000.00
	Instructor	28,000.00
	Secretary	4,500.00
	Benefits and Overhead	16,250.00
	Expendables	12,000.00
	Misc.	3,000.00
		$178,750.00

NOTE: This calculation suggests costs for academic preparation only; it does not include observation, simulator training or coaching for NRC license examination.

ESTIMATED LIBRARY MATERIAL COST.

Library materials for this technology, predicated on 1979 costs, may be estimated from the following:

Initial Costs	Minimum
References	$ 1,500.00
Journals	200.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.).	50.00
	$ 1,350.00

Annual Costs	
References	$ 175.00
Journals	175.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.).	50.00
	$ 500.00